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ELECTRO-MAGNETISM, ELECTROTYPE, PHOTOGRAPHY,
AND DAGUERREOTYPE;

TO WHICH ARE ADDED
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DESIGNED FOR
THE USE OF SCHOOLS AND ACADEMIES.

ILLUSTRATED BY THREE HUNDRED ENGRAVINGS.

BY J. L. COMSTOCK, M. D.

OR OF INTRODUCTION TO MINERALOGY, ELEMENTS OF CHEMISTRY, INTRODUCTION TO BOTANY,
OUTLINES OF GEOLOGY, OUTLINES OF PHYSIOLOGY, NATURAL HISTORY OF BIRDS, ETC.

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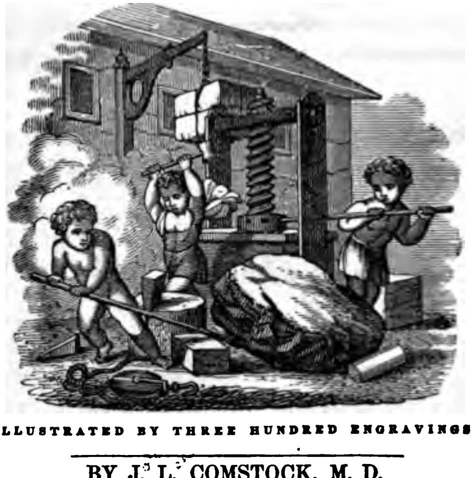

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with those of the paragraphs; and nearly all the old cuts have been re-engraved, and about fifty new ones added.

And, finally, perhaps the author will be excused for adding, that besides the circulation of this work in England, Scotland, and Prussia, there have been printed, and sold more than half a million copies in this country.

J. L. C.

HARTFORD, *April*, 1852.

NATURAL PHILOSOPHY, &c.

CHAPTER I.

THE PROPERTIES OF BODIES

TURAL PHILOSOPHY, or the *Science of Nature*, has for its s the investigation of the properties of all natural bodies heir mutual action on each other. The term *Physics* has ilar meaning.

A BODY *is any substance of which we can gain a knowl- by our senses. Hence, air, water, and earth, in all their fications, are called bodies.*

There are certain properties which are common to all s. These are called the essential properties of bodies. are *Impenetrability*, *Extension*, *Figure*, *Divisibility*, *In-* and *Attraction*.

IMPENETRABILITY.—By impenetrability, is meant that two s can not occupy the same space at the same time, or, that ltimate particles of matter can not be penetrated. Thus, essel be exactly filled with water, and a stone or any other ance heavier than water, be dropped into it, a quantity of r will overflow, just equal to the size of the heavy body. shows that the stone only separates or displaces the parti- of water, and therefore that the two substances can not ex- the same place at the same time. If a glass tube open e bottom, and closed with the thumb at the top, be pressed n into a vessel of water, the liquid will not rise up and fill tube, because the air already in the tube resists it; but if thumb be removed, so that the air can pass out, the water instantly rise as high on the inside of the tube as it is on

---

at are the objects of natural philosophy? 1. What is a body? 2. Mention al bodies. What are the essential properties of bodies? 3. What is meant by *etrability?* How is it proved that air and water are impenetrable?

the outside. This shows that the air is impenetrable to the water.

4. If a nail be driven into a board, in common language, it is said to penetrate the wood, but in the language of philosophy, it only *separates*, or *displaces* the particles of the wood. The same is the case, if the nail be driven into a piece of lead; the particles of the lead are separated from each other, and crowded together, to make room for the harder body, but the particles themselves are by no means penetrated by the nail.

5. When a piece of gold is dissolved in an acid, the particles of the metal are divided, or separated from each other, and diffused in the fluid, but the particles of gold are supposed still to be entire, for if the acid be removed, we obtain the gold again in its solid form, just as though its particles had never been separated.

6. EXTENSION.—*Every body, however small, must have length, breadth, and thickness, since no substance can exist without them. By extension, therefore, is only meant these qualities. Extension has no respect to the size, or shape of a body.*

7. The size and shape of a block of wood a foot square is quite different from that of a walking-stick. But they both equally possess length, breadth, and thickness, since the stick might be cut into little blocks, exactly resembling in shape the large one. And these little cubes might again be divided until they were only the hundredth part of an inch in diameter, and still it is obvious that they would possess length, breadth, and thickness, for they could yet be seen, felt, and measured. But suppose each of these little blocks to be again divided a thousand times, it is true we could not measure them, but still they would possess the quality of extension, as really as they did before division, the only difference being in respect to dimensions.

8. FIGURE OR FORM *is the result of extension, for we can not conceive that a body has length and breadth, without its also having some kind of figure, however irregular.*

9. Some solid bodies have certain or determinate forms which are produced by nature, and are always the same, wherever they are found. Thus, a crystal of quartz has six sides, while a garnet has twelve sides, these numbers being invariable. Some solids are so irregular, that they can not be

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4. When a nail is driven into a board or piece of lead, are the particles of these bodies penetrated or separated? **5.** Are the particles of gold dissolved, or only separated by the acid? **6.** What is meant by extension? **7.** In how many directions do bodies possess extension? **8.** Of what is figure or form the result? Do all bodies possess figure? **9.** What solids are regular in their forms?

ıpared with any mathematical figure. This is the case h the fragments of a broken rock, chips of wood, fractured ıs, &c.; these are called *amorphous.*

.0. Fluid bodies have no determinate forms, but take their pes from the vessels in which they happen to be placed.

.1. Divisibility.—*By the divisibility of matter, we mean t a body may be divided into parts, and that these parts may in be divided into other parts.*

12. It is quite obvious, that if we break a piece of marble › two parts, these two parts may again be divided, and that process of division may be continued until these parts are small as not individually to be seen or felt. But as every ly, however small, must possess extension and form, so we ı conceive of none so minute but that it may again be died. There is, however, possibly a limit, beyond which lies can not actually be divided, for there may be reason to ieve that the atoms of matter are indivisible by any means our power. But under what circumstances this takes place, whether it is in the power of man during his whole life, to verize any substance so finely, that it may not again be ken, is unknown.

13. We can conceive, in some degree, how minute must be ı particles of matter, from circumstances that every day come hin our knowledge.

14. A single grain of musk will scent a room for years, and l lose no appreciable part of its weight. Here, the particles musk must be floating in the air of every part of the room, ıerwise they could not be every where perceived.

15. Gold is hammered so thin, as to take 282,000 leaves to ke an inch in thickness. Here, the particles still adhere each other, notwithstanding the great surface which they 'er,—a single grain being sufficient to extend over a surface fifty square inches.

16. Indestructibility.—*This term means that nothing is troyed.* The ultimate particles of matter, however widely ıy may be diffused, are not individually destroyed, or lost, t under certain circumstances, may again be collected into a ly without change of form. Mercury, water, and many ıer substances, may be converted into vapor, or distilled in

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What bodies are irregular? 11. What is meant by divisibility of matter? Is 'e any limit to the divisibility of matter? 12. Are the atoms of matter divisible? What examples are given of the divisibility of matter? 15. How many leaves of l does it take to make an inch in thickness? How many square inches may a n of gold be made to cover? 16. Under what circumstances may the particles ıatter again be collected in their original form?

close vessels, without any of their particles being lost. In such cases, there is no decomposition of the substances, but only a change of form by the heat, and hence the mercury and water assume their original state again on cooling.

17. Where bodies suffer decomposition or decay, their elementary particles, in like manner, are neither destroyed nor lost, but only enter into new arrangements or combinations with other bodies.

18. When a piece of wood is heated in a close vessel, such as a retort, we obtain water, an acid, several kinds of gas, and there remains a black, porous substance, called *charcoal.* The wood is thus decomposed, or destroyed, and its particles take a new arrangement, and assume new forms, but that nothing is lost, is proved by the fact that if the water, acid, gases, and charcoal, be collected and weighed, they will be found exactly as heavy as the wood was before distillation.

19. Bones, flesh, or any other animal substance, may in the same manner be made to assume new forms, without losing a particle of the matter which they originally contained.

20. The decay of animal or vegetable bodies in the open air, or in the ground, is only a process by which the particles of which they were composed, change their places and assume new forms.

21. The decay and decomposition of animals and vegetables on the surface of the earth form the soil, which nourishes the growth of vegetables; and these, in their turn, form the nutriment of animals. Thus is there a perpetual change from life to death, and from death to life, and as constant a succession in the forms and places, which the particles of matter assume. Nothing is lost, and not a particle of matter is struck out of existence. The same matter of which every living animal, and every vegetable was formed since the creation, is still in existence. As nothing is lost or annihilated, so it is probable that nothing has been added, and that we, ourselves, are composed of particles of matter as old as the creation. In time, we must, in our turn, suffer decomposition, as all forms have done before us, and thus resign the matter of which we are composed, to form new existences.

22. INERTIA.—*Inertia means passiveness or want of power.*

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17. What is meant by indestructibility? 18. When bodies suffer decay, are their particles lost? 19. What becomes of the particles of bodies which decay? 21. Is it probable that any matter has been annihilated or added, since the first creation? What is said of the particles of matter of which we are made?

s, matter is, of itself, equally incapable of putting itself in ion, or of bringing itself to rest when in motion.

3. It is plain that a rock on the surface of the earth never iges its position in respect to other things on the earth. It of itself no power to move, and would, therefore, forever lie unless moved by some external force. This fact is proved he experience of every person, for we see the same objects g in the same positions all our lives. Now, it is just as true, inert matter has no power to bring itself to rest, when once in motion, as it is that it can not put itself in motion when est, for having no life, it is perfectly passive, both to motion rest; and therefore either state depends entirely upon cir-istances.

4. Common experience proving that matter does not put f in motion, we might be led to believe, that rest is the nat- state of all inert bodies; but a few considerations will show motion is as much the natural state of matter as rest, and either state depends on the resistance, or impulse, of ex-ial causes.

5. If a cannon-ball be rolled upon the ground, it will soon se to move, because the ground is rough, and presents imped-nts to its motion; but if it be rolled on the ice, its motion continue much longer, because there are fewer impediments, consequently, the same force of impulse will carry it much her. We see from this, that with the same impulse, the ance to which the ball will move must depend on the im-iments it meets with, or the resistance it has to overcome. suppose that the ball and ice were both so smooth as to re-ve as much as possible the resistance caused by friction, then obvious that the ball would continue to move longer, and to a greater distance. Next, suppose we avoid the friction the ice, and throw the ball through the air, it would then tinue in motion still longer with the same force of projection, ause the air alone presents less impediment than the air and and there is now nothing to oppose its constant motion, ex-t the resistance of the air, and its own weight, or gravity.

26. If the air be exhausted, or pumped out of a vessel by ans of an air-pump, and a common top, with a small, hard nt, be set in motion in it, the top will continue to spin for

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What does inertia mean? 24. Is rest or motion the natural state of matter? Why does the ball roll farther on the ice than on the ground? What does this re? Why, with the same force of projection, will a ball move further through air than on the ice? 26. Why will a top spin, or a pendulum swing, longer in an usted vessel than in the air?

hours, because the air does not resist its motion. A pendulum, set in motion, in an exhausted vessel, will continue to swing, without the help of clock-work, for a whole day, because there is nothing to resist its perpetual motion but the small friction at the point where it is suspended, and gravity.

27. We see, then, that it is the resistance of the air, of friction, and of gravity, which cause bodies once in motion to cease moving, or come to rest, and that dead matter, of itself, is equally incapable of causing its own motion, or its own rest.

28. We have perpetual examples of the truth of this doctrine, in the moon, and other planets. These vast bodies move through spaces which are void of the obstacles of air and friction, and their motions are the same that they were thousands of years ago, or at the beginning of creation.

29. ATTRACTION.—*By attraction is meant that property or quality in the particles of bodies, which makes them tend toward each other.*

30. We know that substances are composed of small atoms or particles of matter, and that it is a collection of these, united together, that form all the objects with which we are acquainted. Now, when we come to divide, or separate any substance into parts, we do not find that its particles have been united or kept together by glue, little nails, or any such mechanical means, but that they cling together by some power, not obvious to our senses. This power we call *Attraction*, but of its nature or cause, we are entirely ignorant. Experiment and observation, however, demonstrate that this power pervades all material things, and that under different modifications, it not only makes the particles of bodies adhere to each other, but is the cause which keeps the planets in their orbits as they pass through the heavens.

31. Attraction has received different names, according to the circumstances under which it acts.

32. The force which keeps the particles of matter together, to form bodies, or masses, is called *Attraction of cohesion.* That which inclines different masses toward each other, is called *Attraction of gravitation.* That which causes liquids to rise in tubes, is called *Capillary attraction.* That which forces

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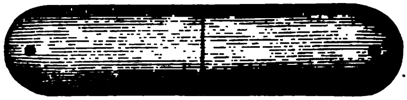
27. What are the causes which resist the perpetual motion of bodies? 28. Where have we an example of continued motion without the existence of air and friction? 29. What is meant by attraction? 30. What is known about the cause of attraction? Is attraction common to all kinds of matter, or not? What effect does this power have upon the planets? 31. Why has attraction received different names? 32. How many kinds of attraction are there? How does the attraction of cohesion operate? What is meant by attraction of gravitation? What by capillary attraction?

rticles of substances of different kinds to unite, is known the name of *Chemical attraction.* That which causes edle to point constantly toward the poles of the earth, is *stic attraction;* and that which is excited by friction in substances, is known by the name of *Electrical at-*
n.

The following illustrations, it is hoped, will make each f attraction distinct and obvious to the mind of the student.

ATTRACTION OF COHESION *acts only at insensible distances, en the particles of bodies apparently touch each other.*

FIG. 1.



Cohesion.

. Take two of lead, *Fig.* round form, h in diame- d two inches flatten one f each and through it re-hole for a string. Make the other ends of each as h as possible, by cutting them with a sharp knife. If now nooth surfaces be brought together, with a slight turning ire, they will adhere with such force that two men can pull them apart by the two strings.

In like manner, two pieces of plate glass, when their es are cleaned from dust, and they are pressed together, dhere with considerable force. Other smooth substances t the same phenomena.

This kind of attraction is much stronger in some bodies n others. Thus, it is stronger in the metals than in most substances, and in some of the metals it is stronger than ers. In general it is most powerful among the particles id bodies, weaker among those of liquids, and probably ly wanting among elastic fluids, such as air and the gases.

Thus, a small iron wire will hold a suspended weight any pounds, without having its particles separated; the les of water are divided by a very small force, while those are still more easily moved among each other. These nt properties depend on the force of cohesion with which veral particles of these bodies are united.

Vhat by chemical attraction? What is that which makes the needle point the pole? How is electrical attraction excited? 53. Give an example of cohe-
raction? 37. In what substances is cohesive attraction the strongest? In bstances is it the weakest? 38. Why are the particles of fluids more easily ed than those of solids?

39. When the particles of fluids are left to arrange themselves according to the laws of attraction, the bodies which they compose assume the form of a globe or ball.

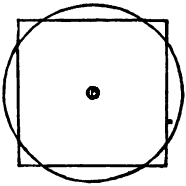
40. Drops of water thrown on an oiled surface, or on wax,—globules of mercury,—hailstones,—a drop of water adhering to the end of the finger,—tears running down the cheeks, and dew-drops on the leaves of plants, are all examples of this law of attraction. The manufacture of shot is also a striking illustration. The lead is melted and poured into a sieve, at the height of about two hundred feet from the ground. The stream of lead, immediately after leaving the sieve, separates into round globules, which, before they reach the ground, are cooled and become solid, and thus are formed the shot used by sportsmen.

41. To account for the globular form in all these cases, we have only to consider that the particles of matter are mutually attracted toward a common center, and in liquids being free to move, they arrange themselves accordingly.

42. In all figures except the globe or ball, some of the particles must be nearer the center than others. But in a body that is perfectly round, every part of the outside is exactly at the same distance from the center.

43. Thus, the corners of a cube, or square, are at much greater distances from the center than the sides, while the circumference of a circle or ball is every where at the same distance from it. This difference is shown by *Fig.* 2, and it is quite obvious, that if the particles of matter are equally attracted toward the common center, and are free to arrange themselves, no other figure could possibly be formed, since then every part of the outside is equally attracted.

FIG. 2.



Globular form.

44. The sun, earth, moon, and indeed all the heavenly bodies, are illustrations of this law, and therefore were probably in so soft a state when first formed, as to allow their particles freely to arrange themselves accordingly.

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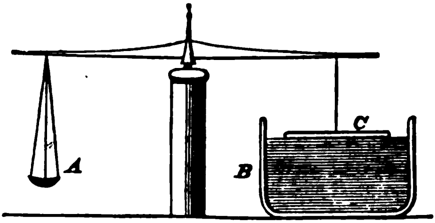
39. What form do fluids take, when their particles are left to their own arrangement? 40. Give examples of this law. 41. How is the globular form which liquids assume accounted for? If the particles of a body are free to move, and are equally attracted toward the center, what must be its figure? 43. Why must the figure be a globe? 44. What great natural bodies are examples of this law?

DHESION.—The attraction between solids and liquids d *adhesion*. This is well illustrated by means of *Fig*. 3. ry nice- ice the copper, eans of in the nd then e vessel , B, un- copper, in more luid un- etal just it. Now ng weights in A, it will be found that the metal ad- the water with so much force, that if the plate has an about seven inches, it will require a weight of more than rains to raise it from the surface of the water.

FIG. 3.



Adhesion between solids and liquids.

ATTRACTION OF GRAVITATION.—*As the attraction of unites the particles of matter into masses or bodies, so action of gravitation tends to force these masses toward her, to form those of still greater dimen-*

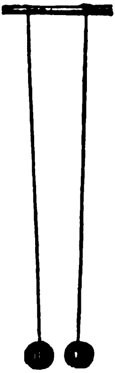
The term gravitation, does not here refer to the weight of bodies, but to action of the masses of matter toward ther, whether downward, upward, or tally.

The attraction of gravitation is mutual, ll bodies not only attract other bodies, themselves attracted.

Two cannon-balls, when suspended by rds, so as to hang quite near each other, nd to exert a mutual attraction, so that of the cords are exactly perpendicular, y approach each other as in *Fig*. 4.

In the same manner, the heavenly bodies, hey approach each other, are drawn out line of their paths, or orbits, by mutual ion.

FIG. 4.



Attraction.

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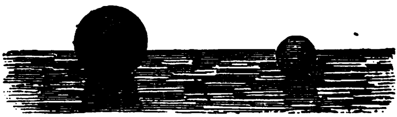
hat explanation can you give of Fig. 3? 46. What is meant by attraction of on? 47. Can one body attract another without being itself attracted? is it proved that bodies attract each other?

50. The force of attraction increases in proportion as bodies approach each other, and by the same law it must diminish in proportion as they recede from each other.

51. Attraction, in technical language, is inversely as the squares of the distances between the two bodies. That is, in proportion as the square of the distance increases, in the same proportion attraction decreases, and so the contrary. Thus, if at the distance of 2 feet, the attraction be equal to 4 pounds, at the distance of 4 feet, it will be only 1 pound; for the square of 2 is 4, and the square of 4 is 16, which is 4 times the square of 2. On the contrary, if the attraction at the distance of 6 feet be 3 pounds, at the distance of 2 feet it will be 9 times as much, or 27 pounds, because 36, the square of 6, is equal to 9 times 4, the square of 2.

52. The law of attraction in masses is very satisfactorily shown by the two little cork balls in *Fig.* 5. They are covered with varnish, or beeswax, to repel the water.

FIG. 5.



Attraction of cork balls.

Two such balls placed on the surface of a dish of water, two or three inches apart, and not near the side of the dish, will soon begin to approach each other; their velocities being in proportion to their sizes, and increasing as their distances diminish, until quite near, when they rush together as though they had life.

53. The intensity of light is found to increase and diminish in the same proportion. Thus, if a board a foot square, be placed at the distance of one foot from a candle, it will be found to hide the light from another board of two feet square, at the distance of two feet from the candle. Now a board of two feet square is just four times as large as one of one foot square, and therefore the light at double the distance being spread over four times the surface, has only one fourth the intensity.

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50. By what law or rule, does the force of attraction increase? 51. Give an example of this rule. 52. How is attraction illustrated by Fig 5? 53. How is it shown that the intensity of light increases and diminishes in the same proportion as the attraction of matter?

The force of the attraction of gravitation, is in proportion quantity of matter the attracting body contains.

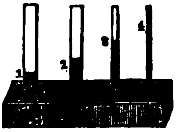
Some bodies of the same bulk contain a much greater ty of matter than others: thus, a piece of lead contains twelve times as much matter as a piece of cork of the dimensions, and therefore a piece of lead of any given ad a piece of cork twelve times as large, will attract each equally.

CAPILLARY ATTRACTION.—*The force by which small or porous substances, raise liquids above their levels, is capillary attraction.*

If a small glass tube be placed in water, the water on side will be raised above the level of that on the outside tube. The cause of this seems to be nothing more than ·dinary attraction of the particles of matter for each other. ides of a small orifice are so near each other as to attract articles of the fluid on their opposite sides, and as all at- on is strongest in the direction of the greatest quantity of ır, the water is raised upward, or in the direction of the h of the tube. On the outside of the tube, the opposite ,es, it is obvious, can not act on the same column of water, herefore the influence of attraction is here hardly percep- in raising the fluid. This seems to be the reason why the rises higher on the inside than on the outside of the tube.

. *Height and size of the bore.*—The ıt to which the fluid will rise, s to depend, not on the specific ty of the fluid, but on the size of ore.

FIG. 6.



Capillary attraction.

I. Thus, if the four glass tubes, n by *Fig.* 6, are respectively the , 20th, 40th, and 80th of an inch iameter, then the height of the in each will be inversely as their ral diameters.

). On comparing the elevation of several fluids in tubes of same diameter, it has been found that water rose more than e times as high as sulphuric acid, though the latter is nearly

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Do bodies attract in proportion to bulk, or quantity of matter? 55. What 1 be the difference of attraction between a cubic inch of lead, and a cubic inch of ? Why would there be so much difference? 56. What is meant by capillary tion? 57. How is this kind of attraction illustrated with glass tubes? Why the water rise higher in the tube than it does on the outside? 58. On what the height of the fluid in capillary tubes depend? 59. Explain Fig. 6. 60. What difference in height between sulphuric acid and water?

twice as heavy as the former, and therefore contains a proportionate quantity of attractive matter. The cause of this difference is unknown.

61. *Prevents evaporation.*—It is very remarkable that capillary attraction prevents evaporation. Thus, fine glass tubes, open at both ends, and containing water, were exposed to the influence of the sun, in the open air, for months, without losing the least portion of their contents.

62. It is well known that mercury in a small vertical tube is depressed around the sides next to the glass; but rises in the center, forming the section of a ball. This is owing to the strong attraction the particles of this metal have for each other, while they appear to have none for the glass. This attraction is beautifully shown by the little bright globules which mercury forms on being thrown on a smooth surface.

63. A great variety of porous substances are capable of capillary attraction. If a piece of sponge or a lump of sugar be placed so that its lowest corner touches the water, the fluid will rise up and wet the whole mass. In the same manner, the wick of a lamp will carry up the oil to supply the flame, though the flame is several inches above the level of the oil. If the end of a towel happens to be left in a basin of water, it will empty the basin of its contents. And on the same principle, when a dry wedge of wood is driven into the crevice of a rock, and afterward moistened with water, as when the rain falls upon it, it will absorb the water, swell, and sometimes split the rock. In Germany mill-stone quarries are worked in this manner.

64. Chemical Attraction *takes place between the particles of substances of different kinds, and unites them into one compound.*

65. This species of attraction takes place only between the particles of certain substances, and is not, therefore, a universal property. It is also known by the name of *chemical affinity*, because the particles of substances having an affinity between them, will unite, while those having no affinity for each other do not readily enter into union.

66. There seems, indeed, in this respect, to be very singular preferences, and dislikes, existing among the particles of matter.

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61. What is said of its preventing evaporation? 62. Why does mercury form a section of a ball in a glass tube? 64. What is the effect of chemical attraction? 65. By what other name is this kind of attraction known? 66. What effect is produced when marble and sulphuric acid are brought together? What is the effect when glass and this acid are brought together? What is the reason of this difference?

? a piece of marble be thrown into sulphuric acid, their s will unite with great rapidity and commotion, and there ult a compound differing in all respects from the acid marble. But if a piece of glass, quartz, gold, or silver, wn into this acid, no change is produced on either, beheir particles have no affinity.

Sulphur and quicksilver, when heated together, will form tiful red compound, known under the name of *vermilion*, ich has none of the qualities of sulphur or quicksilver. Oil and water have no affinity for each other, but pots an attraction for both, and therefore oil and water will vhen potash is mixed with them. In this manner, the own article called *soap* is formed. But the potash has ger attraction for an acid than it has for either the oil or ter; and therefore, when soap is mixed with an acid, the leaves the oil, and unites with the acid, thus destroying l compound, and at the same instant forming a new one. me happens when soap is dissolved in any water con- an acid, as the waters of the sea, and of certain wells. tash forsakes the oil, and unites with the acid, thus leav- oil to rise to the surface of the water. Such waters are *hard*, and will not wash, because the acid renders the a neutral substance.

MAGNETIC ATTRACTION.—There is a certain ore of iron, of which, being suspended by a thread, will always turn its sides to the north. This is called the *loadstone*, or *ul magnet*, and when it is brought near a piece of iron, or mutual attraction takes place, and under certain circum- s the two bodies will come together, and adhere to each This is called *Magnetic Attraction*. When a piece of r iron is rubbed with a magnet, the same virtue is com- ated to the steel, and it will attract other pieces of steel, suspended by a string, one of its ends will constantly toward the north, while the other, of course, points l the south. This is called an *artificial* magnet. The *mag- eedle* is a piece of steel, first touched with the loadstone, en suspended, so as to turn easily on a point. By means s instrument, the mariner guides his ship through the ss ocean. *See Magnetism.*

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hen sulphur and quicksilver are combined, what is formed? 68. How may water be made to unite? What is the composition thus formed called? es an acid destroy this compound? What is the reason that hard water will h? 69. What is a natural magnet? What is meant by magnetic attraction? an artificial magnet? What is a magnetic needle? What is its use?

70. Electrical Attraction.—When a piece of glass, or sealing-wax, is rubbed with the dry hand, or a piece of cloth, and then held toward any light substance, such as hair or thread, the light body will be attracted by it, and will adhere for a moment to the glass or wax. The influence which thus moves the light body is called *Electrical Attraction.* When the light body has adhered to the surface of the glass for a moment, it is again thrown off, or repelled, and this is called *Electrical Repulsion. See Electricity.*

71. We have thus described and illustrated all the universal or inherent properties of bodies, and have also noticed the several kinds of attraction which are peculiar, namely, Chemical, Magnetic, and Electrical. There are still several properties to be mentioned. Some of them belong to certain kinds of matter in a peculiar degree, while other kinds possess them but slightly, or not at all. These properties are as follows:

72. Density.—*This property relates to the compactness of bodies, or the number of particles which a body contains within a given bulk. It is closeness of texture.*

73. Bodies which are most dense, are those which contain the least number of pores. Hence, the density of the metals is much greater than that of wood. Two bodies being of equal bulk, that which weighs most is most dense. Some of the metals may have this quality increased by hammering, by which their pores are filled up, and their particles are brought nearer to each other. The density of air is increased by forcing more into a close vessel than it naturally contained.

74. Rarity.—*This is the quality opposite to density, and means that the substance to which it is applied is porous and light.* Thus, air, water, and ether are rare substances, while gold, lead, and platina are dense bodies.

75. Hardness.—*This property is not in proportion, as might be expected, to the density of the substance, but to the force with which the particles of a body cohere, or keep their places.*

76. Glass, for instance, will scratch gold or platina, though these metals are much more dense than glass. It is probable, therefore, that these metals contain the greatest number of particles, but that those of the glass are more firmly fixed in their places.

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70. What is meant by electrical attraction? What is electrical repulsion? 71. What properties of bodies have been described? 72. What is density? 73. What bodies are most dense? How may this quality be increased in metals? 74. What is rarity? What are rare bodies? What are dense bodies? 75. How does hardness differ from density? 76. Why will glass scratch gold or platina?

Some of the metals can be made hard or soft at pleasure. steel, when heated, and then suddenly cooled, becomes r than glass; while, if allowed to cool slowly, it is soft, and .e.

ELASTICITY *is that property in bodies by which, after forcibly compressed, or bent, they regain their original when the force is removed.*

Some substances are highly elastic, while others want roperty entirely. The separation of two bodies after im- is a proof that one or both are elastic. In general, most and dense bodies possess this quality in greater or less de-

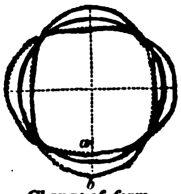
Ivory, glass, marble, flint, and ice, are elastic solids. 'ory ball, dropped upon a marble slab, will bound nearly e height from which it fell, and no mark will be left on :. India rubber is exceedingly elastic, and, on being thrown ly against a hard body, will bound to an amazing distance. , when hardened in a particular manner, and wrought into in forms, possesses this property in the highest degree. h-springs, and those of carriages, as well as sword-blades, xamples. Gold, silver, copper, and platina, also have this rty in a degree.

. Putty, dough, and wet clay are examples of the entire of elasticity; and if either of these be thrown against an diment, they will be flattened, stick to the place they touch, never, like elastic bodies, regain their former shapes.

. Among fluids, water, oil, and in general all such substances e denominated *liquids*, are nearly inelastic, while air, and gaseous fluids, are the most elastic of all bodies.

. *Change of Form.*—The change of in an elastic body, as an India rubber is shown by *Fig.* 7, where its side, riking an impediment, is compressed but instantly springs to *b*; the dark between them being the surface in natural state.

FIG 7.



Change of form.

. BRITTLENESS *is the property which ers substances easily broken, or sepa- l into irregular fragments. This erty belongs chiefly to hard bodies.*

. It does not appear that brittleness is entirely opposed to

What metal can be made hard or soft at pleasure? 78. What is meant by city? 79. How is it known that bodies possess this property? Mention seve- stic solids. 80. Give examples of inelastic solids. 81. Do liquids possess this rty? What are the most elastic of all substances? 82. Explain Fig. 7. 83. What ttleness?

elasticity, since, in many substances, both these properties are united. Glass is the standard, or type of brittleness; and yet a ball, or fine threads of this substance, are highly elastic, as may be seen by the bounding of the one, and the springing of the other. Brittleness often results from the treatment to which substances are submitted. Iron, steel, brass, and copper, become brittle when heated and suddenly cooled; but if cooled slowly, they are not easily broken.

85. MALLEABILITY.—*Capability of being drawn under the hammer or rolling-press.*

This property belongs to some of the metals, but not to all, and is of vast importance to the arts and conveniences of life.

86. The malleable metals are platina, gold, silver, iron, copper, lead, tin, and some others. Antimony, bismuth, and cobalt, are brittle metals. Brittleness is, therefore, the opposite of malleability.

87. Gold is the most malleable of all substances. It may be drawn under the hammer so thin that light may be seen through it. Copper and silver are also exceedingly malleable.

88. DUCTILITY *is that property in substances which renders them susceptible of being drawn into wire.*

89. We should expect that the most malleable metals would also be the most ductile; but experiment proves that this is not the case. Thus, tin and lead may be drawn into thin leaves, but can not be drawn into small wire. Gold is the most malleable of all the metals, but platina is the most ductile. Dr. Wollaston drew platina into threads not much larger than a spider's web.

90. TENACITY, *in common language called toughness, refers to the force of cohesion among the particles of bodies.*

Tenacious bodies are not easily pulled apart. There is a remarkable difference in the tenacity of different substances. Some possess this property in a surprising degree, while others are torn asunder by the smallest force.

91. *Tenacity of Wood.*—The following is a tabular view of the absolute cohesion of the principal kinds of timber employed in the arts and in building, showing the weight which would rend a rod an inch square, and also the length of the rod, which, if suspended, would be torn asunder by its own weight.

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84. Are brittleness and elasticity ever found in the same substance? Give examples. How are iron, steel, and brass made brittle? 85. What does malleability mean? 86. What metals are malleable, and what are brittle? 87. Which is the most malleable metal? 88. What is meant by ductility? 89. Are the most malleable metals the most ductile? 90. What is meant by tenacity? From what does this property arise?

It appears, by experiment, that the following is the ave-
enacity of the kinds of woods named; but it is found that
is much difference in the strength of the same species,
ven of the different parts of the same tree.

The first line refers to the weight, and the other to the
, the wood being an inch square.

	Pounds.	Feet.
Teak, ...	12,915	36,049
Oak, ...	11,880	32,900
Sycamore, . . .	9,630	35,800
Beech, ...	12,225	38,940
Ash, ...	14,130	39,050
Elm, ...	9,540	40,500
Larch, ...	12,240	42,160

Tenacity of the Metals.—The metals differ much more
y in their tenacity than the woods. According to the ex-
ents of Mr. Rennie, the cohesive power of the several
s named below, each an inch square, is equal to the num-
pounds marked in the table, while the feet indicate the
required to separate each metal by its own weight.

	Pounds.	Feet.
Cast steel, . .	134,256	39,455
Malleable iron, . .	72,064	19,740
Cast iron, ...	19,096	6,110
Yellow brass, . .	17,958	5,180
Cast copper, . . .	19,072	5,093
Cast tin, . . .	4,736	1,496
Cast lead, . . .	1,824	348

e cohesion of fluids it is difficult to measure, though some
tion of this property is derived by the different sizes of
rops of each on a plane surface.

. RECAPITULATION.—The common or essential properties
ies are, Impenetrability, Extension, Figure, Divisibility, In-
and Attraction. Attraction is of several kinds, viz. attraction
hesion, attraction of Gravitation, Capillary attraction, Chem-
ttraction, Magnetic attraction, and Electrical attraction.

The peculiar properties of bodies are, Density, Rarity, Hard-
Elasticity, Brittleness, Malleability, Ductility, and Tenacity.

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ive the names of the most tenacious sorts of wood. 94. What metals are most
us? What metals are least tenacious? 95. What are the essential properties
ies? How many kinds of attraction are there? 96. What are the peculiar
ties of bodies?

CHAPTER II.

GRAVITY.

97. The *force by which bodies are drawn toward each other in the mass, and by which they descend toward the earth when let fall from a height, is called the force of gravity.*

98. The attraction which the earth exerts on all bodies near its surface, is called *terrestrial gravity;* and the force with which any substance is drawn downward, is called its *weight.*

99. All falling bodies tend downward, or toward the center of the earth, in a straight line from the point where they are let fall. If, then, a body descends, in any part of the world, the line of its direction will be perpendicular to the earth's surface. It follows, therefore, that two falling bodies, on opposite parts of the earth, mutually fall toward each other.

100. Suppose a cannon-ball to be disengaged from a height opposite to us, on the other side of the earth, its motion in respect to us would be upward, while the downward motion from where we stand would be upward in respect to those who stand opposite to us on the other side of the earth.

101. In like manner, if the falling body be a quarter, instead of half the distance round the earth from us, its line of direction will be directly across, or at right-angles with the line already supposed.

102. This will be readily understood by *Fig.* 8, where the circle is supposed to be the circumference of the earth, A, the ball falling toward its upper surface, where we stand; B, a ball falling toward the opposite side of the earth, but ascending in respect to us; and D, a ball descending at the distance of a quarter of the circle from the other two, and crossing the line of their direction at right-angles.

103. It will be obvious, therefore, that what we call *up* and *down*, are merely relative terms; and that what is down in re-

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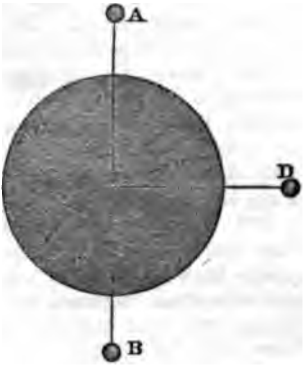
97. What is gravity? 98. What is terrestrial gravity? 99. To what point in the earth do falling bodies tend? 100. In what direction will two falling bodies, from opposite parts of the earth, tend in respect to each other? 101. In what direction will one from half-way between them meet their line? 102. How is this shown by Fig. 8? 103. Are the terms *up* and *down* relative or positive in their meaning?

FIG. 8.



Direction of Falling Bodies.

to us, is up in respect se who live on the te side of the earth, the contrary. Conse- y, *down* every where toward the center of rth ; and *up*, from the of the earth, because ies descend toward the center from whatever iey are let fall. This ə apparent when we ər that, as the earth over every 24 hours, carried with it through ints A, D, and B, *Fig.* l, therefore, if a body osed to fall from the A, say at 12 o'clock, and the same to fall again from the oint above the earth at 6 o'clock, the two lines of direction at right-angles, as represented in the figure, for that part earth which was under A at 12 o'clock, will be under D at ck, the earth having in that time performed one quarter laily revolution. At 12 o'clock at night, if the body be ed to fall again, its line of direction will be at right-an- th that of its last descent, and consequently, it will *as-* respect to the point from which it fell 12 hours before, e the earth would have then gone through one half her otation, and the point A would be at B.

VELOCITY OF FALLING BODIES.

The velocity of every falling body is uniformly accele- n its approach toward the earth, from whatever height it

If a rock is rolled from a steep mountain, its motion is slow and gentle ; but, as it proceeds downward, it moves erpetually increased velocity, seeming to gather fresh very moment, until its force is such that every obstacle ome.

The principle of increased velocity as bodies descend

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s understood by *down* in any part of the earth ? Suppose a ball be let fall then at 6 o'clock, in what direction would the lines of their descent meet r ? 104. What is said concerning the motions of falling bodies ? 105. How reased velocity illustrated ? 106. Explain Fig. 9.

from a height, is curiously illustrated by pouring molasses or thick syrup from an elevation to the ground. The bulky stream, *Fig.* 9, of perhaps two inches in diameter where it leaves the vessel, as it descends, is reduced to the size of a straw, or knitting-needle; but what it wants in bulk is made up in velocity, for the small stream at the ground will fill a vessel just as soon as the large one at the outlet.

FIG. 9.

Increased Velocity.

107. For the same reason, a man may leap from a chair without danger, but if he jumps from the house-top, his velocity becomes so much increased before he reaches the ground, as to endanger his life by the blow.

It is found, by experiment, that the motion of a falling body is accelerated in regular mathematical proportions.

These increased proportions do not depend on the increased weight of the body, because it approaches nearer the center of the earth, but on the constant operation of the force of gravity, which perpetually gives new impulses to the falling body, and increases its velocity.

108. It has been ascertained, by experiment, that a body falling freely, and without resistance, passes through a space of 16 feet and 1 inch during the first second of time. Leaving out the inch, which is not necessary for our present purpose, the ratio of descent is as follows:

109. If the height through which a body falls in one second of time be known, the height which it falls in any proposed time may be computed. For since the height is proportional to the square of the time, the height through which it will fall in *two* seconds will be *four* times that which it falls through in *one* second. In *three* seconds it will fall through *nine* times that space; in *four* seconds *sixteen* times that of the first second; in *five* seconds *twenty-five* times, and so on in this proportion.

The following, therefore, is a general rule to find the height through which a body will fall in any given time.

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107. Why is there more danger in jumping from the house-top than from a chair? 108. What number of feet does a falling body pass through in the first second? 109. If a body fall from a certain height in two seconds, what proportion to this will it fall in four seconds?

|. *Rule.—Reduce the given time to seconds; take the*
of the number of seconds in the time, and multiply the
through which the body falls in one second by that num-
d the result will be the height sought.

.. The following table exhibits the height in feet, and the
ponding times in seconds.

ne	1	2	3	4	5	6	7	8	9	10
ght	1	4	9	16	25	36	49	64	81	100

w, as the body falls at the rate of 16 feet during the first
l, this number, according to the rule, multiplied by the
of the time, that is, by the numbers expressed in the sec-
ne, will show the actual distance through which the body

. Thus we have for the *first* second 16 feet; for the end
second; 4×16=64 feet; *third,* 9×16=144; *fourth,*
6=256; *fifth,* 25×16=400; *sixth,* 36×16=576;
h, 49×16=784; and for the 10 seconds 1600 feet.

. If, on dropping a stone from a precipice, or into a well,
unt the seconds from the instant of letting it fall until we
t strike, we may readily estimate the height of the preci-
r the depth of the well. Thus, suppose it is 5 seconds in
, then we only have to square the seconds, and multiply
y the distance the body falls in one second. We have
×5=25, the square, which 25×16=400 feet, the depth
well.

. Thus it appears, that to ascertain the velocity with
a body falls in any given time, we must know how many
fell during the first second: the velocity acquired in one
l, and the space fallen through during that time, being the
mental elements of the whole calculation, and all that are
ary for the computation of the various circumstances of
bodies.

. The difficulty of calculating exactly the velocity of a
body from actual measurement of its height, and the
which it takes to reach the ground, is so great, that no ac-
computation could be made from such an experiment.

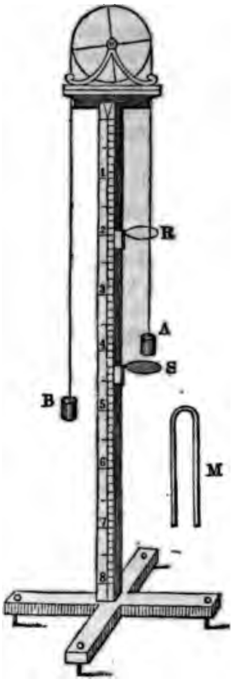
. **Atwood's Machine.**—This difficulty has, however, been
me by a curious piece of machinery invented by Mr. At-
This consists of an upright pillar, with a wheel on the

What is the rule by which the height from which a body falls may be found? w many feet will a body fall in 10 seconds? 113. If the stone is 5 seconds in how deep is the well? 116. Is the velocity of a falling body calculated from measurement, or by a machine?

top, as shown by *Fig.* 10. The weights A and B are of the same size, and are made to balance each other exactly, being connected by a thread passing over the wheel. The ring, R, admits the weight, A, to fall through it in its passage to the stage, S, on which it rests. The ring and stage slide up and down, and are fastened by a thumb-screw. The pillar is a graduated scale, and M is a small bent wire, weighing a quarter of an ounce, and longer than the diameter of the ring.

117. When the machine is to be used, the weight, A, is drawn up to the top of the scale, and the ring and stage are placed a certain number of inches from each other. The small bar, M, is then placed across the weight, A, by means of which it is made slowly to descend. When it has descended to the ring, the small weight, M, is taken off by the ring, and thus the two weights are left equal to each other. Now it must be observed, that the motion and descent of the weight, A, are entirely owing to the gravitating force of the weight, M, until it arrives at the ring, R, when the action of gravity is suspended, and the large weight continues to move downward to the stage, in consequence of the velocity it had acquired previously to that time.

FIG. 10.



Atwood's Machine.

118. To comprehend the accuracy of this machine, it must be understood that the velocities of gravitating bodies are supposed to be equal, whether they are large or small, this being the case when no calculation is made for the resistance of the air. Consequently, the weight of a quarter of an ounce placed on the large weight, A, is a representative of all other solid

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116 Describe the operation of Mr. Atwood's machine for estimating the velocities of falling bodies. 117. After the small weight is taken off by the ring, why does the large weight continue to descend? 118. Does his machine show the actual velocity of a falling body, or only its increase?

descending bodies. The slowness of its descent, when compared with freely gravitating bodies, is only a convenience by which its motion can be accurately measured, for it is the *increase* of velocity which the machine is designed to ascertain, and not the *actual* velocity of falling bodies.

119. Now it will be readily comprehended, that in this respect it makes no difference how slowly a body falls, *provided it follows the same laws as other descending bodies*, and it has already been stated, that all estimates on this subject are made from the known distance a body descends during the first second of time.

120. It follows, therefore, that if it can be ascertained exactly, how much faster a body falls during the third, fourth, or fifth second, than it did during the first second, we should be able to estimate the distance it would fall during all succeeding seconds.

121. If, then, by means of a pendulum beating seconds, the weight, A, should be found to descend a certain number of inches during the first second, and another certain number during the next second, and so on, the ratio of acceleration would be precisely ascertained, and could be easily applied to the falling of other bodies; and this is the use to which this instrument is applied.

122. It will be readily conceived, that solid bodies falling from great heights, must ultimately acquire an amazing velocity by this proportion of increase. An ounce ball of lead, let fall from a certain height toward the earth, would thus acquire a force ten or twenty times as great as when shot out of a rifle.

123. By actual calculation, it has been found that were the moon to lose her projectile force, which counterbalances the earth's attraction, she would fall to the earth in four days and twenty hours, a distance of 240,000 miles. And were the earth's projectile force destroyed, it would fall to the sun, without resistance, in sixty-four days and ten hours, a distance of 95,000,000 of miles.

124. Every one knows, by his own experience, the different effects of the same body falling from a great, or small height. A boy will toss up his leaden bullet and catch it with his hand, but he soon learns, by its painful effects, not to throw it

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121. By what means is the ratio of descent found? **122.** Would it be possible for a rifle-ball to acquire a greater force by falling, than if shot from a rifle? **123.** How long would it take the moon to come to the earth, according to the law of increased velocity? How long would it take the earth to fall to the sun? **124.** What familiar illustrations are given of the force acquired by the velocity of falling bodies?

too high. The effects of hailstones on window-glass, animals, and vegetation, are often surprising, and some times calamitous illustrations of the velocity of falling bodies.

125. It has been already stated that the velocities of solid bodies, falling from a given height toward the earth, are equal, or in other words, that an ounce ball of lead will descend in the same time as a pound ball of lead.

This is true in theory, and in a vacuum, but there is a slight difference in this respect in favor of the velocity of the larger body, owing to the resistance of the atmosphere. We, however, shall at present consider all solids, of whatever size, as descending through the same spaces in the same times, this being exactly true when they pass without resistance.

126. To comprehend the reason of this, we have only to consider, that the attraction of gravitation in acting on a mass of matter, acts on every particle it contains; and thus every particle is drawn down equally, and with the same force. The effect of gravity, therefore, is in exact proportion to the quantity of matter the mass contains, and not in proportion to its bulk.

127. A ball of lead of a foot in diameter, and one of wood of the same diameter, are obviously of the same bulk; but the lead contains twelve particles of matter where the wood contains only one, and consequently will be attracted with twelve times the force, and therefore will weigh twelve times as much.

128. *Attraction proportionable to the quantity of matter.*—If, then, bodies attract each other in proportion to the quantities of matter they contain, it follows that if the mass of the earth were doubled, the weights of all bodies on its surface would also be doubled; and if its quantity of matter were tripled, all bodies would weigh three times as much as they do at present.

129. It follows, also, that two attracting bodies, when free to move, must approach each other mutually. If the two bodies contain like quantities of matter, their approach will be equally rapid, and they will move equal distances toward each other. But if the one be small and the other large, the small one will approach the other with a rapidity proportioned to the less quantity of matter it contains.

130. It is easy to conceive, that if a man in one boat pulls at

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125. Will a small and a large body fall through the same space in the same time? 126. On what parts of a mass of matter does the force of gravity act? Is the effect of gravity in proportion to bulk, or quantity of matter? 127. What is the difference between a ball of lead and one of wood, of the same size? 128. Were the mass of the earth doubled, how much more should we weigh? 129. Suppose one body moving toward another, three times as large, by the force of gravity what would be their proportional velocities? 130. How is this illustrated?

a rope attached to another boat, the two boats, if of the same size, will move toward each other at the same rate; but if the one be large, and the other small, the rapidity with which each moves will be in proportion to its size, the large one moving with as much less velocity as its size is greater.

131. A man in a boat, pulling a rope attached to a ship, seems only to move the boat; but that he really moves the ship is certain, when it is considered that a thousand boats pulling in the same manner would make the ship meet them half way.

It appears, therefore, that an equal force acting on bodies containing different quantities of matter, moves them with different velocities, and that these velocities are in an inverse proportion to their quantities of matter.

In respect to *equal forces*, it is obvious that in the case of the ship and single boat, they were moved toward each other by the same force, that is, the force of a man pulling by a rope. The same principle holds in respect to attraction, for all bodies attract each other equally, according to the quantities of matter they contain; and since all attraction is mutual, no body attracts another with a greater force than that by which it is attracted.

132. Suppose a body to be placed at a distance from the earth, weighing two hundred pounds; the earth would then attract the body with a force equal to two hundred pounds, and the body would attract the earth with an equal force, otherwise their attraction would not be equal and mutual. Another body, weighing ten pounds, would be attracted with a force equal to ten pounds, and so of all bodies according to the quantity of matter they contain; each body being attracted by the earth with a force equal to its own weight, and attracting the earth with an equal force.

133. If, for example, two boats be connected by a rope, and a man in one of them pulls with a force equal to 100 pounds, it is plain that the force on each vessel would be 100 pounds. For if the rope were thrown over a pulley, and a man were to pull at one end with a force of 100 pounds, it is plain it would take 100 pounds at the other end to balance. See *Fig.* 11.

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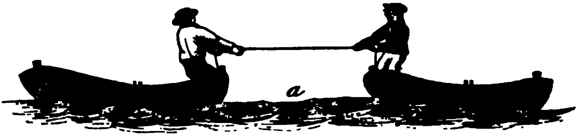
131. Does a large body attract a small one with any more force than it is attracted? 132. Suppose a body weighing 200 pounds to be placed at a distance from the earth, with how much force does the earth attract the body? With what force does the body attract the earth? 133. Suppose a man in one boat pulls with a force of 100 pounds at a rope fastened to another boat, what would be the force on each boat? How is this illustrated?

FIG. 11.



Attraction illustrated.

134. *Attracting bodies approach each other.*—It is inferred from the above principles, that all attracting bodies which are free to move, mutually approach each other, and therefore that the earth moves toward every body which is raised from its surface, with a velocity and to a distance proportional to the quantity of matter thus elevated from its surface. But the velocity of the earth being as many times less than that of the falling body as its mass is greater, it follows that its motion is not perceptible to us.

The following calculation will show what an immense mass of matter it would take, to disturb the earth's gravity in a perceptible manner.

135. If a ball of earth, equal in diameter to the tenth part of a mile, were placed at the distance of the tenth part of a mile from the earth's surface, the attracting powers of the two bodies would be in the ratio of about 512 millions of millions to one. For the earth's diameter being about 8000 miles, the two bodies would bear to each other about this proportion. Consequently, if the tenth part of a mile were divided into 512 millions of millions of equal parts, one of these parts would be nearly the space through which the earth would move toward the falling body. Now, in the tenth part of a mile there are about 6400 inches, consequently this number must be divided into 512 millions of millions of parts, which would give the eighty thousand millionth part of an inch through which the earth would move to meet a body the tenth part of a mile in diameter.

ASCENT OF BODIES.

136. Having now explained and illustrated the influence of gravity on bodies moving downward and horizontally, it remains to show how matter is influenced by the same power when bodies are thrown upward, or contrary to the force of gravity.

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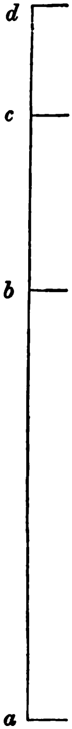
134. Do all attracting bodies approach each other? Suppose the body falls toward the earth, is the earth set in motion by its attraction? Why is not the earth's motion toward it perceptible? 135. What distance would a body, the tenth part of a mile in diameter, placed at the distance of a tenth part of a mile, attract the earth toward it?

FIG. 12.



137. What has been stated in respect to the velocity of falling bodies is reversed in respect to those which are thrown upward, for as the motion of a falling body is increased by the action of gravity, so it is retarded by the same force when projected from the center of gravity.

A bullet shot upward, every instant loses a part of its velocity, until having arrived at the highest point from whence it was thrown, it then returns again to the earth.

138. The same law that governs a descending body, governs an ascending one, only that their motions are reversed.

139. The same ratio is observed to whatever distance the ball is propelled, for as the height to which it is thrown may be estimated from the space it passes through during the first second, so its returning velocity is in a like ratio to the height to which it was sent.

140. This will be understood by *Fig.* 12. Suppose a ball to be propelled from the point *a*, with a force which would carry it to the point *b* in the first second, to *c* in the next, and to *d* in the third second. It would then remain nearly stationary for an instant, and in returning would pass through the same spaces in the same time, only that its direction would be reversed. Thus, it will fall from *d* to *c* in the first second, to *b* in the next, and to *a* in the third.

141. Now the momentum of a moving body is as its velocity and its quantity of matter, and hence the same ball will fall with the same force that it rises. For instance, a ball shot out of a rifle, with force sufficient to overcome a certain impediment, on returning would again overcome the same impediment.

142. It has been doubted, even by good authority, whether the principle above enunciated is true—that is, whether a rising and a falling body observe the same law of motion, only, that they are reversed. On this point we quote Dr. Lardner, who, perhaps, is not inferior to any other authority.

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137. What effect does the force of gravity have on bodies moving upward? 138. Are upward and downward motion governed by the same laws? 140. Explain Fig. 12. What is the difference between the upward and returning velocity of the same body? 141. What is said of the returning force of a rifle-ball? 142. What doubts have been expressed on this subject?

"143. All the circumstances attending the accelerated descent of falling bodies, are exhibited in a reversed order when a body is projected upward.

"Thus, if a body be projected vertically upward, with the velocity which it would acquire in falling freely during one second, the body so projected will rise exactly to the height from which it would have fallen in one second, and at that point of its ascent, it will have the velocity which it would have at the same point, if it had descended."—*Hand Book of Natural Philosophy*, (London, 1851,) p. 116.

144. It has been estimated that a leaden ball (122) falling from a sufficient height, would acquire a much greater force than if shot from a rifle.

It is understood that these estimates refer only to dense bullets, as those of lead, or other metals, on which the atmosphere has the least resistance.

145. It is stated that attempts have been made to test this principle by shooting rifle-balls vertically, and observing with what force they descended, by the depth they penetrated wooden impediments.

But this would hardly be within the art of gunnery, unless the mark erected for the returning ball should be more extensive than experimenters would be willing to construct.

MOTION ON INCLINED PLANES.

146. *Bodies falling down inclined planes follow the same laws of motion as those falling freely, only that their velocities are diminished in proportion as the planes are more or less inclined.*

147. This is illustrated by *Fig.* 13, where let *b* be an inclined plane, and A, G, the vertical line of the same length, the letters on each marking the points to which the falling body is supposed to reach in 1, 2, 3, 4, and 5 seconds. Now suppose two balls to be dismissed at the same instant from A, the one falling freely, and the other along the plane. Then, to find the difference in their velocities, draw perpendicular lines from the points, 1, 2, 3, 4, and 5, along the inclined plane, and extend these lines to B, C, D, E, F, G, of the vertical line, and these points will respectively mark the difference in their velocities. Thus, at the end of the first second, one of the balls will arrive at B, and

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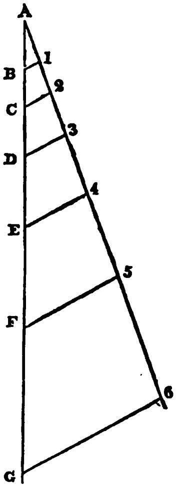
143. What is the quotation from Dr. Lardner? 144. What estimates have been made with respect to the fall of a rifle-ball? 145. What is said of the experiment of shooting rifle-balls vertically? 146. What are the laws of motion down inclined planes? 147. Explain Fig. 13.

the other at *b*, and so in these proportions until they fall to the earth.

148. It will therefore be observed, that although the ball which falls down the plane is retarded in its motion by friction, still it follows the same law as the other, both being uniformly accelerated in their descent by the force of gravity.

FIG. 13.



Fall on Inclined Plane.

FALL OF LIGHT BODIES.

149. *It has been stated that the earth's attraction acts equally on all bodies containing equal quantities of matter, and that in vacuo, all bodies, whether large or small, descend from the same heights in the same time.* (125.)

There is, however, a great difference in the quantities of matter which bodies of the same bulk contain, and consequently a difference in the resistance which they meet with in passing through the air.

150. Now, the fall of a body containing a large quantity of matter in a small bulk, meets with little comparative resistance, while the fall of another, containing the same quantity of matter, but of larger size, meets with more in comparison, for two bodies of the same size, meet with exactly the same resistance. Thus, if we let fall a ball of lead, and another of cork, of two inches in diameter each, the lead will reach the ground before the cork, because, though meeting with the same resistance, the lead has the greatest power of overcoming it.

151. This, however, does not affect the truth of the general law, already established, *that the weights of bodies are as the quantities of matter they contain.* It only shows that the pressure of the atmosphere prevents bulky and porous substances from falling with the same velocity as those which are compact or dense.

152. Were the atmosphere removed, all bodies, whether light or heavy, large or small, would descend with the same velocity. This has been ascertained by experiment in the following manner:

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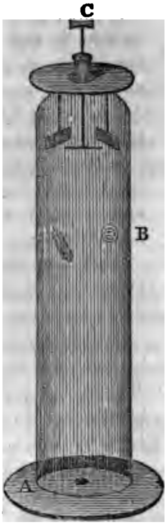
148. What does the explanation of the figure prove? 149. What is said of the fall of bodies? 150. Why will not a sack of feathers and a stone of the same size fall through the air in the same time? 151. Does this affect the truth of the general law, that the weights of bodies are as their quantities of matter? 152. What would be the effect on the fall of light and heavy bodies, were the atmosphere removed?

The *air-pump* is an instrument by means of which the air can be pumped out of a close vessel, as will be seen under the article Pneumatics. Taking this for granted at present, the experiment is made in the following manner:

FIG. 14.



Feather and Guinea.

153. On the plate of the air-pump, A, place the tall jar, B, which is open at the bottom, and has a brass cover fitted closely to the top. Through the cover let a wire pass, air-tight, having a small cross at the lower end. On each side of this cross place a little stage, and so contrive them that by turning the wire by the handle, C, these stages shall be upset. On one of the stages place a guinea or piece of lead, and on the other place a feather. When this is arranged, let the air be exhausted from the jar by the pump, and then turn the handle, C, so that the guinea and feather may fall from their places, and it will be found that they will both strike the plate at the same instant. Thus is it demonstrated, that were it not for the resistance of the atmosphere, a bag of feathers and one of guineas would fall from a given height with the same velocity, and in the same time.

CHAPTER III.

MOTION.

154. Motion *may be defined, a continued change of place, with regard to a fixed point.*

155. Without motion there would be no rising nor setting of the sun—no change of seasons—no fall of rain—no building of houses, and finally no animal life. Nothing can be done without motion, and therefore without it, the whole universe would be at rest and dead.

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153. How is it proved that a feather and a guinea will fall through equal spaces in the same time, where there is no resistance? 154. How will you define motion? 155. What would be the consequence were all motion to cease?

156. In the language of philosophy, the power which puts a body in motion is called *force*. Thus, it is the force of gravity that overcomes the *inertia* of bodies, and draws them toward the earth. The force of water and steam gives motion to machinery, &c.

157. For the sake of convenience, and accuracy in the use of terms, motion is divided into two kinds, viz. *absolute* and *relative.*

158. Absolute motion is a change of place with regard to a fixed point, and is estimated without reference to the motion of any other body. When a man rides along the street, or when a vessel sails through the water, they are both in absolute motion.

159. Relative motion is a change of place in a body, with respect to another body, also in motion, and is estimated from that other body exactly as absolute motion is from a fixed point.

160. The absolute velocity of the earth in its orbit from west to east, is 68,000 miles in an hour; that of Mars, in the same direction, is 55,000 miles per hour. The earth's relative velocity, in this case, is 13,000 miles per hour from west to east. That of Mars, comparatively, is 13,000 miles from east to west, because the earth leaves Mars that distance behind her, as she would leave a fixed point.

161. *Rest*, in the common meaning of the term, is the opposite of motion, but it is obvious that rest is often a relative term, since an object may be perfectly at rest with respect to some things, and in rapid motion in respect to others.

162. Thus, a man sitting on the deck of a steamboat, may move at the rate of fifteen miles per hour, with respect to the land, and still be at rest with respect to the boat. And so, if another man was running on the deck of the same boat at the rate of fifteen miles the hour in a contrary direction, he would be stationary in respect to a fixed point, and still be running with all his might, with respect to the boat.

VELOCITY OF MOTION.

163. *Velocity is the rate of motion at which a body moves from one place to another.*

Velocity is independent of the weight or magnitude of the moving body. Thus, a cannon-ball and a musket-ball, both flying at the rate of a thousand feet in a second, have the same velocities.

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156. What is that power called which puts a body in motion? 157. How is motion divided? 158. What is absolute motion? 159. What is relative motion? 160. What is the earth's relative velocity in respect to Mars? 161. What is rest? 162. In what respect is a man in a steamboat at rest, and in what respect does he move? 163. What is velocity?

164. Velocity is said to be *uniform*, when the moving body passes over equal spaces in equal times. If a steamboat moves at the rate of ten miles every hour, her velocity is uniform. The revolution of the earth from west to east is a perpetual example of uniform motion.

165. Velocity is *accelerated*, when the rate of motion is increased, and the moving body passes through unequal spaces in equal times. Thus, when a falling body moves sixteen feet during the first second, and forty-eight feet during the next second, and so on, its velocity is accelerated. A body falling from a height freely through the air, is the most perfect example of this kind of velocity.

166. *Retarded velocity*, is when the rate of motion of the body is constantly decreased, and it is made to move slower and slower. A ball thrown upward into the air, has its velocity constantly retarded by the attraction of gravitation, and consequently, it moves slower every moment. (137.)

VELOCITIES OF CERTAIN MOVING BODIES.

167. Objects moving:—	Miles per hour.	Feet per second.
Man walking,	3	4½
Horse trotting,	7	10½
Swiftest race-horse,	60	88
Railway train, (English)	32	47
" (American)	18	26
" (Belgian)	25	36
" (French)	27	40
" (German)	24	35
Swift English steamers,	14	20
American steamers on the Hudson,	18	26
Fast sailing vessels,	10	14
Current of slow rivers,	3	4½
" of rapid rivers,	7	10
Moderate wind,	7	10
A storm, with wind,	36	52
A hurricane, in hot climates,	80	117
Air rushing into a vacuum,	884	1296
Common musket-ball,	850	1246
A rifle-ball,	1000	1466
A 24-lb. cannon-ball,	1600	2346
A bullet from an air-gun,	466	683
Sound, heat at 32°,	748	1090
" do at 60°,	762	1118
Earth's velocity round the sun,	67,374	98,815
" diurnal motion at equator,	1037	1520

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164. When is velocity uniform? 165. When is velocity accelerated? Give illustrations of these two kinds of velocity. 166. What is meant by retarded velocity? Give an example of retarded velocity.

168. The above, from Lardner's Mechanics, may be useful for occasional reference. We have omitted the fractional parts with respect to the seconds, as being difficult to remember, and useless for the present purpose. In regard to American locomotive speed, it is at the present time probably nearly one-third too small. The comparative velocities of balls from fire-arms differ from those given by some other authorities, but on this subject we have made no experiments.

FORCE, OR MOMENTUM OF MOVING BODIES.

169. *The velocities of bodies are equal, when they pass over equal spaces in the same times; but the force with which bodies, moving at the same rate, overcome impediments, is in proportion to the quantity of matter they contain.* This power, or force, is called the *momentum* of the moving body.

170. Thus, if two bodies of the same weight move with the same velocity, their momenta will be equal.

171. Two vessels, each of a hundred tons, sailing at the rate of six miles an hour, would overcome the same impediments or be stopped by the same obstructions. Their momenta would therefore be the same.

The force or momentum of a moving body, is in proportion to its quantity of matter, and its velocity.

172. A large body moving slowly, may have less momenta than a small one moving rapidly. Thus, a bullet shot out of a gun, moves with much greater force than a stone thrown by the hand.

173. *The momentum of a body is found by multiplying its quantity of matter by its velocity per second.* Thus, if the velocity be 2, and the weight 2, the momentum will be 4. If the velocity be 6, and the weight of the body 4, the momentum will be 24.

174. If a moving body strikes an impediment, the force with which it strikes, and the resistance of the impediment, are equal. Thus, if a boy throw his ball against the side of the house, with the force of 3, the house resists it with an equal force, and the ball rebounds. If he throws it against a pane of glass with the same force, the glass having only the power of 2 to resist, the ball will go through the glass, still retaining one-third of its force.

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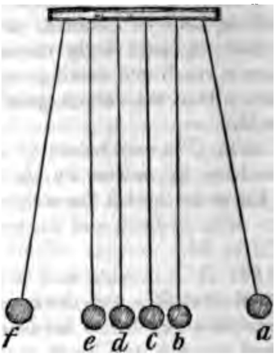
168. What is said of the speed of our locomotives? **169.** What is meant by the momentum of a body? **170.** When will the momentum of two bodies be equal? **171.** Give an example. **172.** When has a small body a greater momentum than a large one? **173** By what rule is the momentum of a body found? **174.** When a moving body strikes an impediment, which receives the greatest shock?

175. **Pile Driver.**—This machine consists of a frame and pulley, by which a large piece of cast iron, called the *hammer*, is raised to the height of 30 or 40 feet, and then let fall on the end of a beam of wood called a *pile*, and by which it is driven into the ground. When the hammer is large, and the height considerable, the force, or momentum, is tremendous, and unless ths pile is hooped with iron, will split it into fragments.

176. Now the momentum of a body being in proportion to its weight and velocity conjointly, to find it, we must multiply their two sums together.

Suppose then the hammer, weighing 2000 pounds, is elevated two seconds of time above the head of the pile, then, according to the law of falling bodies, (110,) it would fall 64 feet, this being the rate of its velocity. Then 64 × 2000, being the velocity and quantity of matter, gives 64 tons as the momentum. But according to the same law, this force is immensely increased by a small increase of time, for if we add two seconds of time, the rate of velocity at the instant of striking would be 256 feet per second, and thus 256 × 2000 = 512,000 pounds, or 256 tons.

FIG. 15.



Action and Reaction.

177. **Action and Reaction equal.** — *From observations made on the effects of bodies striking each other, it is found that action and reaction are equal; or, in other words, that force and resistance are equal. Thus, when a moving body strikes one that is at rest, the body at rest returns the blow with equal force.*

This is illustrated by the well-known fact, that if two persons strike their heads together, one being in motion, and the other at rest, they are both equally hurt.

178. The philosophy of action and reaction is finely illustrated by a number of ivory balls, suspended by threads, as in *Fig.* 15, so as to touch each

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175. What is a pile driver? 176. If the hammer of this machine weighs 2000 pounds, and falls 2 seconds, what will be the momentum? If the fall be 3 seconds, what is the momentum? 177. What is the law of action and reaction? How is this illustrated?

other. If the ball *a* be drawn from the perpendicular, and then let fall, so as to strike the one next to it, the motion of the falling ball will be communicated through the whole series, from one to the other. None of the balls except *f*, will, however, appear to move. This will be understood, when we consider that the reaction of *b* is just equal to the action of *a*, and that each of the other balls, in like manner, act, and react, on the other, until the motion of *a* arrives at *f*, which, having no impediment, or nothing to act upon, is itself put in motion. It is therefore, reaction, which causes all the balls, except *f*, to remain at rest.

180. It is by a modification of the same principle, that rockets are impelled through the air. The stream of expanded air, or the fire, which is emitted from the lower end of the rocket, not only pushes against the rocket itself, but against the atmospheric air, which, reacting against the air so expanded, sends the rocket along.

181. It was on account of not understanding the principles of action and reaction, that the man undertook to make a fair wind for his pleasure-boat, to be used whenever he wished to sail. He fixed an immense bellows in the stern of his boat, not doubting that the wind from it would carry him along. But on making the experiment, he found that his boat went backward instead of forward. The reason is plain. The reaction of the atmosphere on the stream of wind from the bellows, before it reached the sail, moved the boat in a contrary direction.

182. Had the sail received the whole force of the wind from the bellows, the boat would not have moved at all, for then, action and reaction would have been exactly equal, and it would have been like a man's attempting to raise himself over a fence by the straps of his boots.

REFLECTED MOTION.

183. *It has been stated* (27) *that all bodies when once set in motion, would continue to move straight forward, until some impediment, acting in a contrary direction, should bring them to rest; continued motion without impediment being a consequence of the inertia of matter.*

184. Such bodies are supposed to be acted upon by a single force, and that in the direction of the line in which they move.

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179. When one of the ivory balls strikes the other, why does the most distant one only move? 180. On what principle are rockets impelled through the air? 181. In the experiment with the boat and bellows, why did the boat move backward? 182. Why would it not have moved at all had the sail received all the wind from the bellows? 183. What is said of the continuity of motion?

Thus, a ball sent out of a gun, or struck by a bat, turns neither to the right nor left, but makes a curve toward the earth, in consequence of another force, which is the attraction of gravitation, and by which, together with the resistance of the atmosphere, it is finally brought to the ground.

The kind of motion now to be considered, is that which is produced when bodies are turned out of a straight line by some force, independent of gravity.

A single force, or impulse, sends the body directly forward, but another force, not exactly coinciding with this, will give it a new direction, and bend it out of its former course.

185. If, for instance, two moving bodies strike each other obliquely, they will both be thrown out of the line of their former direction. This is called *reflected* motion, because it observes the same laws as reflected light.

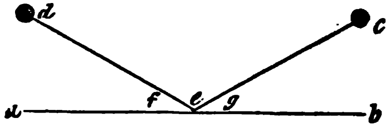
186. The bounding of a ball; the skipping of a stone over the smooth surface of a pond; and the oblique direction of an apple, when it touches a limb in its fall, are examples of reflected motion.

By experiments on this kind of motion, it is found that moving bodies observe certain laws, in respect to the direction they take in rebounding from any impediment they happen to strike.

187. Thus, a ball, striking on the floor, or wall of a room, makes the same angle in leaving the point where it strikes, that it does in approaching it.

188. Suppose *a*, *b*, *Fig.* 16, to be a marble floor, and *c*, to be an ivory ball, which has been thrown toward the floor in the direction of the line *c e;* it will rebound in the direction of the line *e d*, thus making the two angles *f* and *g* exactly equal.

FIG. 16.



Reflected Motion.

189. If the ball approaches the floor under a larger or smaller angle, its rebound will observe the same rule. Thus, if it fell in the line *h k*, *Fig.* 17, its rebound would be in the line

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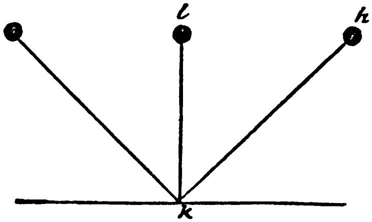
184. Suppose a body is acted on, and set in motion by a single force, in what direction will it move? 185. What is the motion called, when a body is turned out of a straight line by another force? 186. What illustrations can you give of reflected motion? What laws are observed in reflected motion? 187. Suppose a ball to be thrown on the floor in a certain direction, what rule will it observe in rebounding? 188. Explain Fig 16.

FIG. 17.



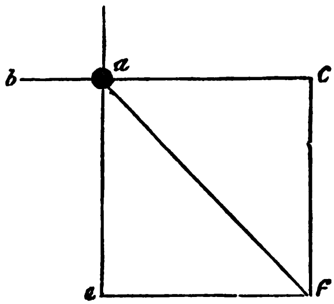
Equal Angles.

k i, and if it was dropped perpendicularly from *l* to *k*, it would return in the same line to *l*. The angle which the ball makes with the perpendicular line, *l k*, in its approach to the floor, is called the *angle of incidence*, and that which it makes in departing from the floor with the same line, is called the *angle of reflection*, and these angles are always equal.

COMPOUND MOTION.

190. *Compound motion is that which is produced by two or more forces, acting in different directions, on the same body, at the same time.* This will be readily understood by a diagram.

FIG. 18.



Compound Motion.

191. Suppose the ball *a*, *Fig.* 18, to be moving with a certain velocity in the line *b c*, and suppose that at the instant when it came to the point *a*, it should be struck with an equal force in the direction of *d e*, then, as it can not obey the direction of both these forces, it will take a course between them, and fly off in the direction of *f*.

The reason of this is plain. The first force would carry the ball from *b* to *c;* the second would carry it from *d* to *e;* and these two forces being equal, gives it a direction just half way between the two, and therefore it is sent toward *f*.

The line *a f*, is called the *diagonal of the square*, and

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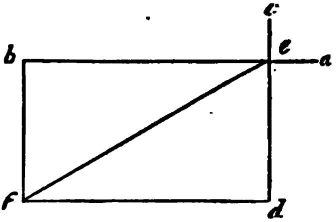
189. What is the angle called, which the ball makes in approaching the floor? What is the angle called, which it makes in leaving the floor? What is the difference between these angles? 190. What is compound motion? 191. Suppose a ball, moving with a certain force, to be struck crosswise with the same force, in what direction will it move?

results from the cross forces, *b* and *d*, being equal to each other. If one of the moving forces is greater than the other, then the diagonal line will be lengthened in the direction of the greater force, and instead of being the diagonal of a square, it will become that of a parallelogram.

192. Suppose the force in the direction of *a b*, should drive the ball with twice the velocity of the cross force *c d*, *Fig.* 19, then the ball would go twice as far from the line *c d*, as from the line *b a*, and *e f* would be the diagonal of a parallelogram whose length is double its breadth.

FIG. 19.



Diagonal Motion.

193. Suppose a boat, in crossing a river, is rowed forward at the rate of four miles an hour, and the current of the river is at the same rate, then the two cross forces will be equal, and the line of the boat will be the diagonal of a square, as in *Fig.* 18. But if the current be four miles an hour, and the progress of the boat forward only two miles an hour, then the boat will go down stream twice as fast as she goes across the river, and her path will be the diagonal of a parallelogram, as in *Fig.* 19, and therefore, to make the boat pass directly across the stream, it must be rowed toward some point higher up the river than the landing-place; a fact well known to boatmen.

194. CIRCUS RIDER.—Those who have seen feats of horsemanship at the circus, are often surprised that when the man leaps directly upward, the horse does not pass from under him, and that in descending he does not fall behind the animal. But it should be considered that, on leaving the saddle, the body of the rider has the same velocity as that of the horse; nor does his leaving the horse by jumping upward, in any degree diminish his velocity in the same direction; his motion being continued by the impulse he had gained from the animal. In this case, the body of the man describes the diagonal of a parallelogram, one side of which is in the direction of the horse's

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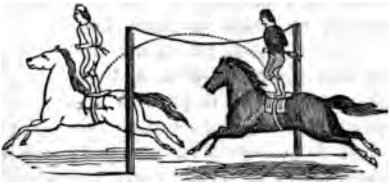
192. Suppose it to be struck with twice its former force, in what direction will it move? What is the line *a f* Fig. 18, called? What is the line *e f*, Fig. 19, called. How are these figures illustrated? Explain Figs. 18 and 19. 193. Explain the motion of the boat? Why does the leaping circus rider form the diagonal of a parallelogram?

motion, and the other perpendicularly upward, in the direction in which he makes the leap.

FIG. 20.



Circus Rider.

195. This will be better understood by *Fig.* 20, where the two forces are illustrated. Had the rider remained on the horse, he would have reached that point, where he meets him after the leap over the iron bar, under which the animal passes. This force the rider gains from the horse. The diagonal force is the result of his own muscular exertion, and by which he raises himself above the bar, still retaining in his leap the velocity of the horse, and thus regains the saddle, as though he had not left it.

The motion of the rider is through the section of a sphere, as shown by the figure, where the horse and rider are shown before and after the leap.

CIRCULAR MOTION.

196. *Circular motion is that of a body in a ring, or circle, and is produced by the action of two forces. By one of these forces, the moving body tends to fly off in a straight line, while by the other it is drawn toward the center, and thus it is made to revolve, or move round in a circle.*

197. The force by which a body tends to go off in a straight line, is called the *centrifugal force;* that which keeps it from flying away, and draws it toward the center, is called the *centripetal force.*

198. Bodies moving in circles are constantly acted upon by these two forces. If the centrifugal force should cease, the moving body would no longer perform a circle, but would approach the center of its own motion. If the centripetal force should cease, the body would instantly begin to move off in a straight line, this being, as we have explained, the direction which all bodies take when acted on by a single force.

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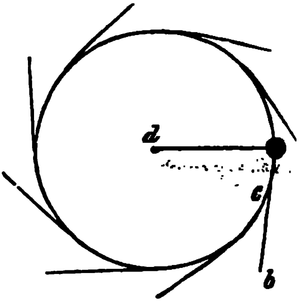
195. Explain Fig. 20, and show on what principle the rider meets his horse after the leap? 196. What is circular motion? How is this motion produced? 197. What is the centrifugal force? What is the centripetal force? 198. Suppose the centrifugal force should cease, in what direction would the body move? Suppose the centripetal force should cease, where would the body go?

FIG. 21



Centrifugal Force.

199. Suppose a cannon-ball, *Fig.* 21, tied with a string to the center of a slab of smooth marble, and suppose an attempt be made to push this ball with the hand in the direction of *b*; it is obvious that the string would prevent its going to that point; but would keep it in the circle. In this case the string is the *centripetal* force.

200. Now suppose the ball to be kept revolving with rapidity, its velocity and weight would cause its centrifugal force; and if the string were cut, when the ball was at the point *c*, for instance, this force would carry it off in the line toward *b*.

The greater the velocity with which a body moves round in a circle, the greater will be the force with which it would tend to fly off in a right line.

Thus, when one wishes to sling a stone to the greatest distance, he makes it whirl round with the greatest possible rapidity, before he lets it go. Before the invention of other warlike instruments, soldiers threw stones in this manner, with great force and dreadful effects.

201. The line about which a body revolves, is called its *axis of motion.* The point round which it turns, or on which it rests, is called the *center of motion.* In *Fig.* 21, the point *d*, to which the string is fixed, is the center of motion. In the spinning-top, a line through the center of the handle to the point on which it turns, is the axis of motion.

In the revolution of a wheel, that part which is at the greatest distance from the axis of motion, has the greatest velocity, and, consequently, the greatest centrifugal force.

202. Suppose the wheel, *Fig.* 22, to revolve a certain number of times in a minute, the velocity of the end of the arm at the point *a*, would be as much greater than its middle at the point *b*, as its distance is greater from the axis of motion, because

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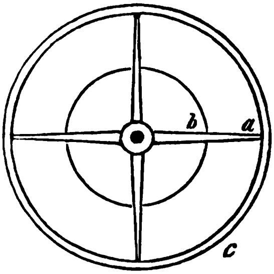
199. What constitutes the centrifugal force of the body moving round in a circle? 200. How is this illustrated? 201. What is the axis of motion? What is the center of motion? Give illustrations? 202. What part of a revolving wheel has the greatest centrifugal force?

FIG. 22.



Revolving Wheel.

it moves in a larger circle, and consequently the centrifugal force of the rim *c*, would, in like manner, be as its distance from the center of motion.

203. Large wheels, which are designed to turn with great velocity, must, therefore, be made with corresponding strength, otherwise the centrifugal force will overcome the cohesive attraction, or the strength of the fastenings, in which case the wheel will fly in pieces. This sometimes happens to the large grindstones used in gun factories, and the stone either flies away piecemeal, or breaks in the middle, to the great danger of the workmen.

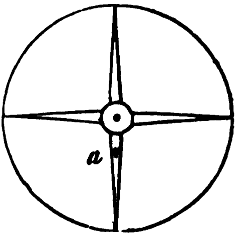
204. Were the diurnal velocity of the earth about seventeen times greater than it is, those parts at the greatest distance from its axis would begin to fly off in straight lines, as the water does from a grindstone when it is turned rapidly.

CENTER OF GRAVITY.

205. *The center of gravity, in any body or system of bodies, is that point upon which the body, or system of bodies, acted upon only by gravity, will balance itself in all positions.*

206. The center of gravity, in a wheel made entirely of wood, and of equal thickness, would be exactly in its center of motion. But if one side of the wheel were made of iron, and the other part of wood, its center of gravity would be changed to some point, aside from the center of the wheel.

FIG. 23.



Center of Gravity.

207. Thus, the center of gravity in the wooden wheel, *Fig.* 23, is at the axis on which it turns; but were the arm *a*, of iron, its center of mo-

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[illegible]. Why must large wheels, turning with great velocity, be strongly made? 204. would be the consequence, were the velocity of the earth seventeen times than it is? 205. Where is the center of gravity in a body? 206. Where is f gravity in a wheel made of wood? If one side is made of wood, and the on, where is the center? 207. Is the center of motion and of gravity same?

tion and of gravity would no longer be the same, but while the center of motion remained as before, the center of gravity would fall to the point *a*. Thus the center of motion and of gravity, though often at the same point, are not always so.

When a body is shaped irregularly, or there are two or more bodies connected, the center of gravity is the point on which they will balance without falling.

FIG. 24.

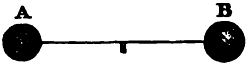
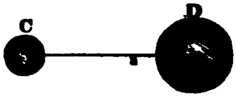


FIG. 25.



208. If the two balls A and B, *Fig.* 24, weigh each four pounds, the center of gravity will be a point on the bar equally distant from each.

But if one of the balls be heavier than the other, then the center of gravity will, in proportion, approach the larger ball. Thus, in *Fig.* 25, if C weighs two pounds, and D eight pounds, this center will be four times the distance from C that it is from D.

209. In a body of equal thickness, as a board, or a slab of marble, but otherwise of an irregular shape, the center of gravity may be found by suspending it, first from one point, and then from another, and marking, by means of a plumb-line, the perpendicular ranges from the point of suspension. The center of gravity will be the point where these two lines cross each other.

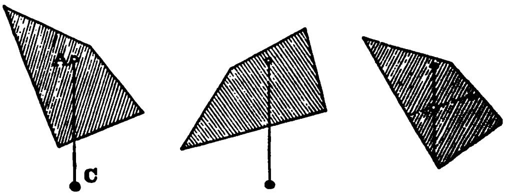


FIG. 26. FIG. 27. FIG. 28.

Finding the Center of Gravity.

Thus, if the irregular shaped piece of board, *Fig.* 26, be suspended by making a hole through it at the point A, and at the

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208. When two bodies are connected, as by a bar between them, where is the center of gravity? 209. In a board of irregular shape, by what method is the center of gravity found?

same point suspending the plumb-line C, both board and line will hang in the position represented in the figure. Having marked this line across the board, let it be suspended again in the position of *Fig.* 27, and the perpendicular line again marked. The point where these lines cross, is the center of gravity, as seen by *Fig.* 28.

210. *Importance of the subject.*—It is often of great consequence, in the concerns of life, that the subject of gravity should be well considered, since the strength of buildings, and of machinery, often depends chiefly on the gravitating point.

Common experience teaches, that a tall object, with a narrow base, or foundation, is easily overturned; but common experience does not teach the reason, for it is only by understanding principles, that practice improves experiment.

211. An upright object will fall to the ground, when it leans so much that a perpendicular line from its center of gravity falls beyond its base. A tall chimney, therefore, with a narrow foundation, such as are commonly built at the present day, will fall with a very slight inclination.

212. Now, in falling, the center of gravity passes through the part of a circle, the center of which is at the extremity of the base on which the body stands. This will be comprehended by *Fig.* 29.

FIG. 29.

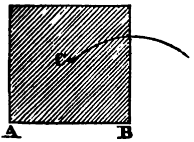
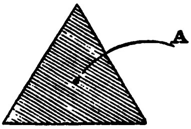


FIG. 30.



Suppose the figure to be a block of marble, which is to be turned over, by lifting at the corner A, the corner B would be the center of its motion, or the point on which it would turn. The center of gravity, C, would, therefore, describe the part of a circle, of which the corner, B, is the center.

213. It will be found that the greatest difficulty in turning over a square block of marble, is in first raising up the center of gravity, for the resistance will constantly become less, in proportion as the point approaches a perpendicular line over the corner B, which, having passed, it will fall by its own gravity.

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210. Why is finding the center of gravity of importance? 211. In what direction must the center of gravity be from the outside of the base, before the object will fall? 212. In falling, the center of gravity passes through part of a circle; where is the center of this circle? 213. In turning over a body why does the force required constantly become less and less?

The difficulty in turning over a body of particular form, will be more strikingly illustrated by the figure of a triangle, or low pyramid.

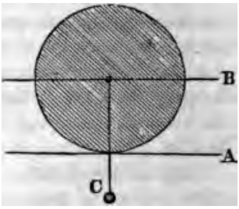
214. In *Fig.* 30, the center of gravity is so low, and the base so broad, that in turning it over, a great proportion of its whole weight must be raised. Hence we see the firmness of the pyramid in theory, and experience proves its truth; for buildings are found to withstand the effects of time, and the commotions of earthquakes, in proportion as they approach this figure.

The most ancient monuments of the art of building, now standing, the pyramids of Egypt, are of this form.

215. *Movement of a Ball.*—When a ball is rolled on a horizontal plane, the center of gravity is not raised, but moves in a straight line, parallel to the surface of the plane on which it rolls, and is consequently always directly over its center of motion.

216. Suppose, *Fig.* 31, A is the plane on which the ball moves, B the line on which the center of gravity moves, and C a plumb-line, showing that the center of gravity must always be over the center of motion, when the ball moves on a horizontal plane—then we shall see the reason why a ball moving on such a plane, will rest with equal firmness in any position, and why so little force is required to set it in motion. For in no other figure does the center of gravity describe a horizontal line over that of motion, in whatever direction the body is moved.

FIG. 31.



217. If the plane is inclined downward, the ball is instantly thrown into motion, because the center of gravity then falls forward of that of motion, or the point on which the ball rests.

218. This is explained by *Fig.* 32, where A is the point on which the ball rests, or the center of motion, B the perpendicular line from the center of gravity, as shown by the plumb-weight C.

219. If the plane is inclined upward, force is required to move the ball in that direction, because the center of gravity

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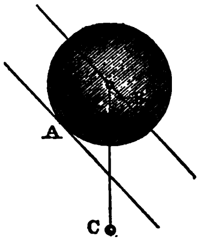
214. Why is there less force required to overturn a cube, or square, than a pyramid of the same weight? 215. When a ball is rolled on a horizontal plane, in what direction does the center of gravity move? Explain Fig. 31. 216. Why does a ball on a horizontal plane rest equally well in all positions? Why does it move with little force? 217. If the plane is inclined downward, why does the ball roll in that direction? 218. Explain Fig. 32. 219. Why is force required to move a ball up an inclined plane?

FIG. 32.

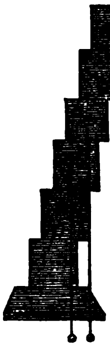


then falls behind that of motion, and therefore this point has to be constantly lifted. This is also shown by *Fig.* 32, only considering the ball to be moving up the inclined plane, instead of down it.

From these principles, it will be readily understood why so much force is required to roll a heavy body, as a hogshead of sugar, for instance, up an inclined plane. The center of gravity falling behind that of motion, the weight is constantly acting against the force employed to raise the body.

220. *Illustration by Blocks.*—One of the best illustrations of this subject may be made by a number of square blocks of wood, placed on each other, as in *Fig.* 33, forming a leaning tower. Where five blocks are placed in this position, the point of gravity is near the center of the third block, and is within the base, as shown by the plumb-line. But on adding another block, the gravitating point falls beyond the base, and the whole will now fall by its own weight.

FIG. 33.



Leaning Tower.

221. The student having such blocks, (and they may be picked up about any joiner's shop,) will convince himself, that however carefully his leaning tower is laid up, it will not stand when the center of gravity falls an inch or two beyond the support.

222. We may learn, from these comparisons, that it is more dangerous to ride in a high carriage than a low one, in proportion to the elevation of the vehicle, and the nearness of the wheels to each other, or in proportion to the narrowness of the base, and the height of the center of gravity. A load of hay, *Fig.* 34, upsets where one wheel rises but little above the other, because it is broader on the top than the distance of the wheels from each other; while a load of stone is very rarely turned over, because the center of gravity is near the earth, and its weight between the wheels, instead of being far above them.

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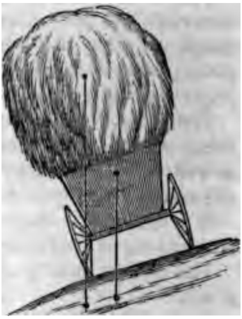
220. Why is a body, shaped like Fig. 33, easily thrown down? Hence, in riding in a carriage, how is the danger of upsetting proportioned? Explain Fig. 33. **221.** How may the point of gravity be found by means of a number of square blocks? **222.** Why will a load of hay upset more readily than one of stone?

223. *Center of gravity in man.*—In man the center of gravity is between the hips, and hence, were his feet tied together, and his arms tied to his sides, a very slight inclination of his body would carry the perpendicular of his center of gravity beyond the base, and he would fall. But when his limbs are free to move, he widens his base, and changes this center at pleasure, by throwing out his arms, as circumstances require.

FIG. 34.



Load of Hay.

When a man runs, he inclines forward, so that the center of gravity may hang before his base, and in this position he is obliged to keep his feet constantly advancing, otherwise he would fall forward.

A man standing on one foot, can not throw his body forward without, at the same time, throwing his other foot backward, in order to keep the center of gravity within the base.

224. A man, therefore, standing with his heels against a perpendicular wall, can not stoop forward without falling, because the wall prevents his throwing any part of his body backward. A person, little versed in such things, agreed to pay a certain sum of money for an opportunity of possessing himself of double the sum, by taking it from the floor with his heels against the wall. The man, of course, lost his money, for in such a posture, one can hardly reach lower than his own knee.

225. The base on which a man is supported, in walking or standing, is his feet, and the space between them. By turning the toes out, this base is made broader, without taking much from its length, and hence persons who turn their toes outward, not only walk more firmly, but more gracefully, than those who turn them inward.

226. In consequence of the upright position of man, he is constantly obliged to employ some exertion to keep his balance. This seems to be the reason why children learn to walk with so much difficulty; for after they have strength to stand, it requires considerable experience so to balance the body as to set one foot before the other without falling.

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223. Where is the center of man's gravity? Why will a man fall with a slight inclination, when his feet and arms are tied? 224. Why can not one who stands with his heels against a wall stoop forward? 225. Why does a person walk most firmly, who turns his toes outward? 226. Why does not a child walk as soon as he can stand?

227. By experience in the art of balancing, or of keeping the center of gravity in a line over the base, men sometimes perform things that, at first sight, appear altogether beyond human power, such as dining with the table and chair standing on a single rope, dancing on a wire, &c.

228. *Illustration by Trees.*—No form, under which matter exists, escapes the general law of gravity, and hence vegetables, as well as animals, are formed with reference to the position of this center, in respect to the base.

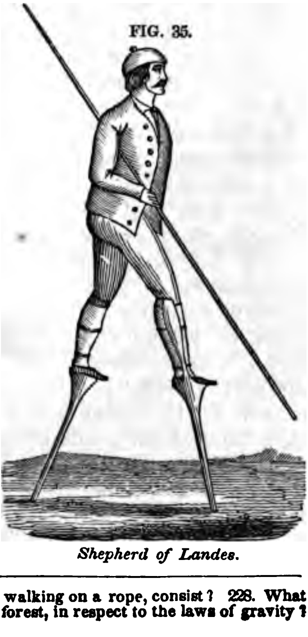
It is interesting, in reference to this circumstance, to observe how exactly the tall trees of the forest conform to this law.

The pine, which grows a hundred feet high, shoots up with as much exactness, with respect to keeping its center of gravity within the base, as though it had been directed by the plumb-line of a master builder. Its limbs toward the top are sent off in conformity to the same law; each one growing in respect to the other, so as to preserve a due balance between the whole.

229. SHEPHERDS OF LANDES.—Men, as already noticed, by practice in the art of balancing, perform feats which are wonderful to all beholders. The shepherds of Landes, in the south of France, are perhaps the only people who apply this art to the common business of life. These men walk on stilts from four to five feet high; and their children, when quite young, who are intended to take the places of their fathers as shepherds, are taught this art in order to qualify them for business.

To strangers, passing their district, these men cut a figure at once ludicrous and surprising. *Fig.* 35. But it is for their own convenience that this singular custom has been adopted, for by this means the feet are kept out of the water which

FIG. 35.



Shepherd of Landes.

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227. In what does the art of balancing, or walking on a rope, consist? 228. What is observed in the growth of the trees of the forest, in respect to the laws of gravity? 229. What principle is involved in Fig. 35.

covers their land in the winter, and from the heated sand in the summer. Besides these comforts, the sphere of vision over a flat country is materially increased by the elevation, so that the shepherd can see his flock at a much greater distance than from the ground.

By habit, it is said these men acquire the art of balancing themselves so perfectly as to run, jump, and dance on these stilts with perfect ease. They walk with surprising quickness, so that footmen have to do their best to keep up with them.

CENTER OF INERTIA, OR INACTIVITY.

230. *It will be remembered that inertia* (22) *is one of the inherent, or essential properties of matter, and that it is in consequence of this property, when bodies are at rest, that they never move without the application of force, and when once in motion, that they never cease moving without some external cause.* (27.)

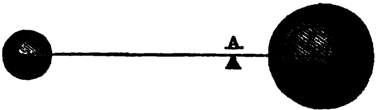
231. Now, inertia, though like gravity, it resides equally in every particle of matter, must have, like it, a center in each particular body, and this center is the same with that of gravity.

232. In a bar of iron, six feet long and two inches square, this center is just three feet from each end, or exactly in the middle. If, therefore, the bar is supported at this point, it will balance equally, and because there are equal weights on both ends, it will not fall.

Now suppose a bar should be raised by raising up the center of gravity, then the inertia of all its parts would be overcome equally with that of the middle. The center of gravity is, therefore, the center of inertia.

233. But, suppose the same bar of iron, whose inertia was overcome by raising the center, to have balls of different weights attached to its ends; then the center of inertia would no longer remain in the middle of the bar, but would be changed to the point A, *Fig.* 36, so that, to lift the whole, this point must be raised, instead of the middle, as before.

FIG. 36.



Center of Inertia.

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230. What effect does inertia exert on bodies at rest? What effect does it have on bodies in motion? 231. Is the center of inertia, and that of gravity, the same? 232. Where is the center of inertia in a body, or a system of bodies? 233. Why is the point of inertia changed, by fixing different weights to the ends of the iron bar?

EQUILIBRIUM.

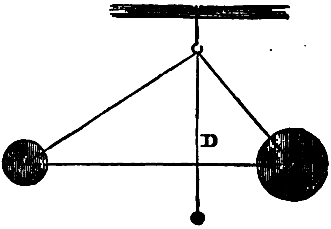
234. *When two forces counteract, or balance each other, they are said to be in equilibrium.*

235. It is not necessary for this purpose that the weights opposed to each other should be equally heavy, for we have just seen that a small weight, placed at a distance from the center of inertia, will balance a large one placed near it. To produce equilibrium, it is only necessary that the weights on each side of the support should mutually counteract each other, or if set in motion, that their momenta should be equal.

236. A pair of scales are in equilibrium when the beam is in a horizontal position.

To produce equilibrium in solid bodies, therefore, it is only necessary to support the center of inertia, or gravity.

FIG. 37.



Equilibrium.

237. If a body, or several bodies, connected, be suspended by a string, as in *Fig.* 37, the point of support is always in a perpendicular line above the center of inertia. The plumb-line, D, cuts the bar connecting the two balls at this point. Were the two weights in this figure equal, it is evident that the hook, or point of support, must be in the middle of the string, to preserve the horizontal position.

238. When a man stands on his right foot, he keeps himself in equilibrium, by leaning to the right, so as to bring his center of gravity in a perpendicular line over the foot on which he stands.

CURVILINEAR, OR BENT MOTION.

239. *We have seen that a single force acting on a body,* (183,) *drives it straight forward, and that two forces acting crosswise, drive it midway between the two, or give it a diagonal direction,* (190.)

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234. What is meant by equilibrium? 235. To produce equilibrium, must the weights be equal? 236. When is a pair of scales in equilibrium? 237. When a body is suspended by a string, where must the support be with respect to the point of inertia? 239. What is meant by curvilinear motion?

Curvilinear motion differs from both these; the direction of the body being neither straight forward nor diagonal, but through a line which is curved.

This kind of motion may be in any direction; but when it is produced in part by gravity, its direction is always toward the earth.

239. A stream of water from an aperture in the side of a vessel, as it falls toward the ground, is an example of a curved line; and a body passing through such a line, is said to have *curvilinear* motion. Any body projected forward, as a cannon-ball, or rocket, falls to the earth in a curved line.

240. It is the action of gravity across the course of the stream, or the path of the ball, that bends it downward and makes it form a curve. The motion is, therefore, the result of two forces, that of projection, and that of gravity.

241. *In jets of water*, the shape of the curve will depend on the velocity of the stream. When the pressure of the water is great, the stream, near the vessel, is nearly horizontal, because its velocity is in proportion to the pressure. When a ball first leaves the cannon, it describes but a slight curve, because its projectile velocity is then greatest.

242. The curves described by jets of water under different degrees of pressure, are readily illustrated by tapping a tall vessel in several places, one above the other.

243. The action of gravity being always the same, the shape of the curve described must depend on the velocity of the moving body; but whether the projectile force be great or small, the moving body, if thrown horizontally, will reach the ground from the same height in the same time.

This, at first thought, would seem improbable; for, without consideration, most persons would assert, that, if two cannons were fired from the same spot at the same instant, and in the same direction, one of the balls falling half a mile, and the other a mile distant, that the ball which went to the greatest distance would take the most time in performing its journey.

244. But it must be remembered, that the projectile force does not in the least interfere with the force of gravity. A ball

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239. What are examples of this kind of motion? 240. What two forces produce this motion? 241. On what does the shape of the curve depend? 242. How are the curves described by jets of water illustrated? 243. What difference is there in respect to the time taken by a body to reach the ground, whether the curve be great or small? 244. Why do bodies, forming different curves from the same height, reach the ground at the same time? Suppose two balls, one flying at the rate of a thousand, and the other at the rate of a hundred feet per second, which would descend most during the second?

flying horizontally, at the rate of a thousand feet per second, is attracted downward with precisely the same force as one flying only a hundred feet per second, and must, therefore, descend the same distance in the same time.

245. The distance to which a ball will gô, depends on the force of impulse given it the first instant, and, consequently, on its projectile velocity. If it moves slowly, the distance will be short; if more rapidly, the space passed over will be greater. It makes no difference, then, in respect to the descent of the ball, whether its projectile motion be fast or slow, or whether it moves forward at all.

246. *Falling of Cannon Balls.*—This may be shown by experiment. Suppose a cannon to be loaded with a ball, and placed on the top of a tower, at such a height from the ground, that it would take just four seconds for the ball to descend from it to the ground, if let fall perpendicularly. Now, sùppose the cannon to be fired in an exact horizontal direction, and, at the same instant, the ball to be dropped toward the ground. They will both reach the ground at the same instant, provided its surface be a horizontal plane from the foot of the tower to the place where the projected ball strikes.

247. *Demonstration.*—This is demonstrated by *Fig.* 38, where A is the cannon from which the ball is to be fired, *a* the vertical line of the descending ball, A, B, 1, *a*, the parallelogram through which the ball passes during the first second.

Now the ball dropped in the vertical direction, will descend 16 feet the first second, increasing its velocity according to the law of falling bodies already explained. Meantime the projected ball passing through the diagonal of the upper parallelogram, will arrive at 1, while the other falls to *a*. During the next second the vertical ball will fall to *b*, while the other, in consequence of its projectile force, will pass through the diagonal of the parallelogram *b*, 2, C, A.

The same laws of descent being continued, it is obvious, that the two balls will reach *d*, 4 at the same instant.

248. From these principles it may be inferred, that the horizontal motion of a body through the air, does not interfere with its gravitating motion toward the earth, and, therefore,

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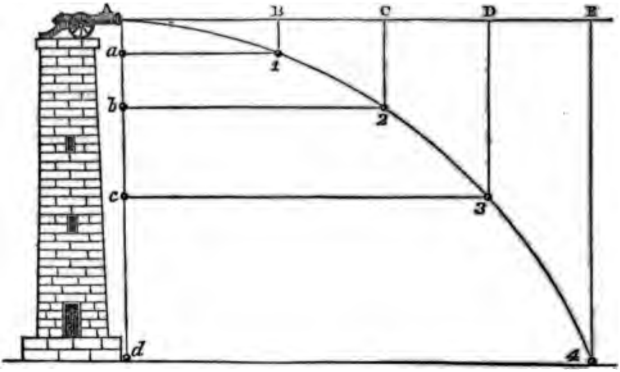
245. Does it make any difference in respect to the descent of the ball, whether it has a projectile motion or not? 246. Suppose, then, one ball be fired from a cannon, and another let fall from the same height at the same instant, would they both reach the ground at the same time? 247. Explain Fig. 38, showing the reason why the two balls will reach the ground at the same time. Why does the ball approach the earth more rapidly in the last part of the curve than in the first part? 248. What is the inference from these principles?

FIG. 38.



Path of a Cannon Ball.

that a rifle-ball, or any other body projected horizontally, will reach the ground in the same period of time as one that is let fall perpendicularly from the same height.

249. The two forces acting on bodies which fall through curved lines, are the same as the centrifugal and centripetal forces, already explained; the centrifugal, in case of the ball, being caused by the powder—the centripetal, being the action of gravity, (199.)

250. Now the space through which a cannon-ball, or any other body, can be thrown, depends on the velocity with which it is projected; for the attraction of gravitation, and the resistance of the air, acting perpetually, the *time* which a projectile can be kept in motion through the air is only a few moments.

Perpetual Revolution.—If the projectile be thrown from an elevated situation, it is plain that it would strike at a greater distance than if thrown on a level, because it would remain longer in the air. Every one knows that he can throw a stone to a greater distance when standing on a steep hill, than when standing on the plain below.

251. Suppose the circle, *Fig.* 39, to be the earth, and A, a high mountain on its surface. Suppose that this mountain

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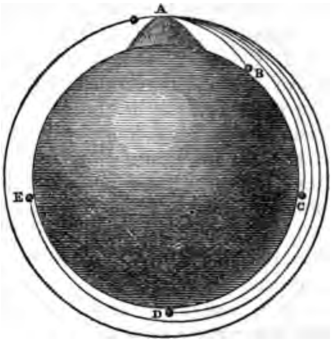
249. What is the force called which throws a ball forward? What is that called which brings it to the ground? 250. On what does the distance to which a projected body may be thrown, depend? Why does the distance depend on the velocity? 251. Suppose the velocity of a cannon-ball shot from a mountain 50 miles high to be ten times its usual rate, where would it stop?

FIG. 39.



Perpetual Revolution of a Ball.

reaches above the atmosphere, or is fifty miles high, then a cannon-ball might perhaps reach from A to B, a distance of eighty or a hundred miles, because the resistance of the atmosphere being out of the calculation, it would have nothing to contend with, except the attraction of gravitation. If, then, one degree of force, or velocity, would send it to B, another would send it to C; and if the force was increased three times, it would fall to D, and if four times, it would pass to E. If, now, we suppose the force to be about ten times greater than that with which a cannon-ball is projected, it would not fall to the earth at any of these points, but would continue its motion until it again came to the point A, the place from which it was first projected.

252. It would now be in equilibrium, the centrifugal force being just equal to that of gravity, and, therefore, it would perform another and another revolution, and so continue to revolve around the earth perpetually.

253. It is these two forces which retain the heavenly bodies in their orbits; and in the case we have supposed, our cannon-ball would become a little satellite, moving perpetually round the earth.

GUNNERY.

254. Law and Force of Projectiles.—Ever since the discovery of gunpowder, the laws of projectiles have been studied with attention, as being of importance in the art of war. Many learned and elaborate works have been published on the subject, but our limits will only admit the insertion of a few of the most important principles of Gunnery.

255. A projectile, as a bullet from a gun, unless it has a

Explain Fig. 39. 252. When would this ball be in equilibrium? Why would not the force of gravity ultimately bring this ball to the earth? 253. After the first revolution, if the two forces continued the same, would not the motion of the ball be perpetual? 254. Why are the laws of projectiles viewed important? 255. What two forces act on projectiles? What is the path of a projectile called?

vertical direction, is acted on by two forces, that of projection, which carries it forward, and that of gravity, which draws it downward. Its path, therefore, is a curve, called a *parabola.*

256. The distance to which the ball will fly, depends on the force of projection, since, if its direction is horizontal, its fall toward the earth by the force of gravity (250) will be the same, whether its velocity be great or small.

257. The resistance of the atmosphere, is the great impediment to the effects of projectile forces. Thus it has been demonstrated that a 24-lb. cannon-ball, discharged at an elevation of 45°, and at the velocity of 2000 feet per second, would, in vacuo, reach the horizon-distance of 125,000 feet, but the resistance of the air limits its range to 7,300 feet.

258. VELOCITY OF THE BALL.—There are several methods of computing the velocity of the ball, one of which is by means of the *Ballistic pendulum.* This is a thick, heavy block of wood, so suspended as to swing freely about on axis, and into this the ball is fired. The weight of the ball, and that of the block being known, the velocity is found, by the degrees of motion given to the pendulum, which is accurately measured by machinery.

259. *Recoil of the Gun.*—Another method of finding the velocity of the ball, is by means of the recoil of the gun. This method is founded on the supposition that the explosive force of the powder, communicates equal quantities of motion to the gun and ball, in opposite directions. Hence, by suspending the gun, loaded with weights, like a pendulum, the extent of its arc of vibration, will indicate the force of the charge, and by knowing the weights of the gun and ball, its velocity is indicated. By such means Dr. Hutton constructed the following table:—

POWDER.	VELOCITY PER SECOND.	DISTANCE.	TIME OF FLIGHT.
Ounces.	Feet.	Feet.	Seconds.
2	800	4100	9
4	1230	5100	12
8	1640	6000	14½
12	1680	6700	15½

260. Experiment shows that the velocity of the ball increases

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256. On what does the distance of a projectile depend? 257. What is said of atmospheric resistance? 258. What is the construction of the ballistic pendulum? 259. What is the other method of estimating the velocity of the ball?

with the charge, to a certain extent, which is peculiar to each gun, after which the increase diminishes the force, until the bore is quite full.

261. The greatest velocity of a ball known, is about 2000 feet per second, and this from a cannon. This velocity diminishes, soon after it leaves the gun.

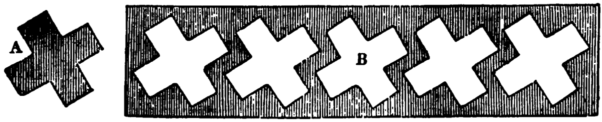
262. *Power and Destruction.*—The penetration of the ball is as the square of its velocity. Hence, when the object is merely to penetrate, as in the breaching of a fortification, the greatest velocity is given. But in naval combats, the utmost velocity is not the most injurious, the most destructive balls being such as merely pierce the ship's sides.

MANUFACTURE OF PERCUSSION CAPS.

263. The processes by which percussion caps are made at the establishment of Mr. McIntyre, in the city of Hartford, Ct., are as follow:—

264. *First.*—The copper is rolled to about the thickness of stout brown paper, and is then cut into strips three-fourths of an inch wide, and several yards long. The end of such a strip being placed between the rollers of a cutting and punching machine, invented for this purpose, the whole, without further attention, is cut into star-like pieces of the form and size represented by *Fig.* 40, A being the piece cut out, and B, the appearance of the strip of copper after the operation.

FIG. 40.



First shape of the Copper.

These pieces are instantly moved, by the same engine, under the punch, by which they are driven through a finely creased die, and are thus formed into caps which fall into a vessel below.

These stellate pieces, being struck by the punch in the center, the extremities are thus brought into contact, but not joined, so that the caps consist of four portions connected at the bottom, like the four quarters of an orange peel.

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260. How far does the velocity of the ball increase with that of the charge? 261. What is the greatest velocity of a ball? 262. What velocity of the ball is most destructive?

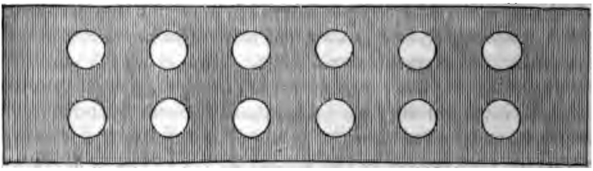
When the caps are exploded by the hammer, these quarters open and thus prevent the tearing of the metal which, if solid, would be apt to fly into fragments and thus endanger the eyes.

265. *Second.*—The caps are next placed in a revolving cylinder containing saw-dust, by which they are made clean and bright.

They are now ready to receive the ***fulminating powder***, the explosion of which sets fire to the powder in the gun-barrel.

The caps are now placed, a handful at a time, on a sheet of iron, three feet long, eight inches wide, and the fourth of an inch thick, pierced with holes a quarter of an inch apart, as shown by *Fig.* 41. This being placed in a horizontal position, and shaken, the caps find their way into the apertures, with their open ends up, in a manner that is quite surprising.

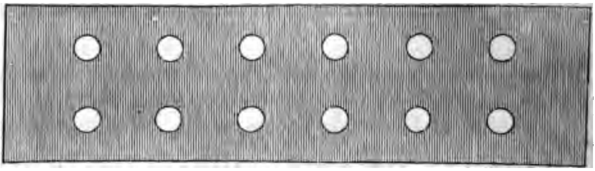
FIG. 41.



Mode of Placing the Caps for Filling.

266. *Third.*—A piece of brass plate, of the exact size of that containing the caps, is pierced with apertures to correspond with each and every cap, but smaller in size, as shown by *Fig.* 42.

FIG. 42.



Mode of Filling.

This plate, being about the sixth of an inch thick, is laid on a smooth surface, and the fulminating compound, a little moistened by gum-water, is rubbed into the apertures with the hand, where it adheres, that remaining on the surface being rubbed off.

267. *Fourth.*—This brass plate, being laid on that containing the caps, each aperture corresponding to a cap, the powder, by means of a brush, is made to fall into the caps.

268. *Fifth.*—The caps are now charged with the powder, in a loose state, and requires a gentle pressure to fix it in its place.

This is done by placing the plate, containing them, as above described, under rows of punches, which are worked with a little cam engine, and by which the punches are lifted, while the plate is moved forward, by means of a click and notches, so as to correspond exactly with the fall of the punches, by the pressure of which, the powder is fixed in its place.

269. *Sixth.*—The best caps are varnished, in order to protect them from moisture. It being the powder only which requires this protection, in France it is done with a little brush on each cap held in the fingers. But Mr. McIntyre has invented a much more expeditious way, and which insures the same quantity in each cap.

This is done by a small machine, consisting of two cams; a click working in horizontal notches, and a crank, by which the whole is moved. On the platform or bed of this, is laid the plate, *Fig.* 41, containing the caps, (268,) and on working the machine, two dozen blunt metallic points are alternately dipped into a little trough containing copal varnish, and then into the caps, these being moved by the click, to correspond with the revolution of the cams by which the motions of these points are produced. In this way hundreds of caps are varnished in a few minutes.

270. *Seventh.*—The edges of the best caps are polished, one at a time, by holding them with pliers for a second on a spindle of steel, revolving a thousand times a minute, the point of which enters the cap, the edge rubbing against a shoulder, by which the work is done.

With two engines, as above described, the proprietor estimates the number of caps made per day, to be about 100,000, a market being always ready for all he can make.

RESULTANT MOTION.

271. ***Resultant motion consists in the operation of two, or more, forces, the joint action of which, results in unity of effect.***

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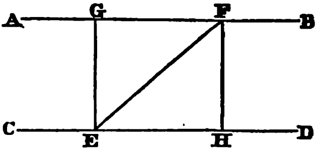
271. What is meant by resultant motion? Suppose two boats sailing at the same rate and in the same direction, if an apple be tossed from one to the other, what will be its direction in respect to the boats?

Suppose two men to be sailing in two boats, each at the rate of four miles an hour, at a short distance opposite to each other, and suppose as they are sailing along in this manner, one of the men throws the other an apple. In respect to the boats, the apple would pass directly across from one to the other, that is, its line of direction would be at right-angles with the sides of the boats. But its actual line through the air would be oblique, or diagonal, in respect to the sides of the boats, because, in passing from boat to boat, it is impelled by two forces, viz., the force of the motion of the boat forward, and the force by which it is thrown by the hand across this motion.

FIG. 43.



Diagonal Motion.

272. This diagonal motion of the apple is called the *resultant*, or the resulting motion, because it is the effect or result of two motions resolved into one. Perhaps this will be more clear by *Fig.* 43, where A B, and C D, are supposed to be the sides of the two boats, and the line E F, that of the apple. Now the apple, when thrown, has a motion with the boat at the rate of four miles an hour, from C toward D, and this motion is supposed to continue just as though it had remained in the boat.

273. Had it remained in the boat during the time it was passing from E to F, it would have passed from E to H. But we suppose it to have been thrown at the rate of eight miles an hour, in the direction toward G; and if the boats are moving south, and the apple thrown toward the east, it would pass in the same time twice as far toward the east as it did toward the south. Therefore, in respect to the boats the apple would pass at right-angles from the side of one to that of the other, because they are both in motion.* But in respect to a right line, drawn from the point where the apple was thrown, and a parallel line with this, drawn from the point where it strikes the other boat, the line of the apple would be oblique. This will be clear, when we consider that, when the apple is thrown, the boats are at the points E and G, and that when it strikes, they are at H and F, these two points being opposite to each other.

What would be its line through the air in respect to the boats? 272. What is this kind of motion called? Why is it called resultant motion? Explain Fig. 43. 273. Why would the line of the apple be actually at right-angles in respect to the boats, but oblique in respect to parallel lines drawn from where it was thrown and where it struck? How is this further illustrated?

The line E F, through which the apple is thrown, is called the diagonal of a parallelogram, as already explained under compound motion.

274. On the above principle, if two ships, during a battle, are sailing before the wind at equal rates, the aim of the gunners will be exactly the same as though they stood still; whereas, if the gunner fires from a ship standing still, at another under sail, he takes his aim forward of the mark he intends to hit, because the ship would pass a little forward while the ball is going to her.

275. And so, on the contrary, if a ship in motion fires at another standing still, the aim must be behind the mark, because, as the motion of the ball partakes of that of the ship, it will strike forward at the point aimed at.

276. For the same reason, if a ball be dropped from the topmast of a ship under sail, it partakes of the motion of the ship forward, and will fall in a line with the mast, and strike the same point on the deck as though the ship stood still.

If a man upon the full run drops a bullet before him from the height of his head, he can not run so fast as to overtake it before it reaches the ground.

It is on this principle, that if a cannon-ball be shot up vertically from the earth, it will fall back to the same point; for, although the earth moves forward while the ball is in the air, yet, as it carries this motion with it, so the ball moves forward, also, in an equal degree, and, therefore, comes down at the same place.

HOROLOGY.

277. *This term, derived from the Greek, means, to indicate the hour. It is the science of time-keeping.*

278. For this purpose, a great variety of instruments have been invented, by some of which, time was measured by the dropping of water, as in the *clepsydra*, or water-clock, in others, by the running of sand, as in the hour-glass, or by the revolution of the sun, by means of the *gnomon*, or sun-dial. But these ancient methods have given place to the modern invention of clocks, regulated by the *pendulum*, and watches, regulated by a *balance-wheel.*

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274. When the ships are in equal motion, where does the gunner take his aim? Why does he aim forward of the mark when the other ship is in motion? 275. If a ship in motion fires at one standing still, where must be the aim? Why, in this case, must the aim be behind the mark? 276. What other illustrations are given of resultant motion? 277. What is the meaning of horology? 278. What were the ancient methods of keeping time?

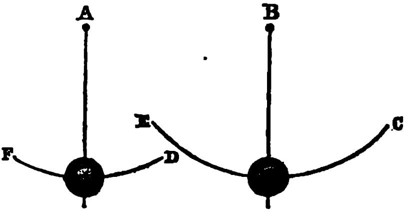
PENDULUM.

279. *A pendulum is a heavy body, such as a piece of brass or lead, suspended by a wire or cord, so as to swing backward and forward.*

When a pendulum swings, it is said to *vibrate;* and that part of a circle through which it vibrates, is called its *arc.*

280. The times of the vibration of a pendulum are very nearly equal, whether it pass through a greater or less part of its arc.

FIG. 44.



Pendulum.

Suppose A and B, *Fig.* 44, to be two pendulums of equal length, and suppose the weights of each are carried, the one to C, and the other to D, and both let fall at the same instant; their vibrations would be equal in respect to time, the one passing through its arc from C to E, and so back again in the same time that the other passes from D to F, and back again.

281. The reason of this appears to be, that when the pendulum is raised high, the action of gravity draws it more directly downward, and it therefore acquires in falling a greater comparative velocity than is proportioned to the trifling difference of height.

282. *Common Clock.*—In the common clock, the pendulum is connected with wheel-work, to regulate the motion of the hands, and with weights, by which the whole is moved. The vibrations of the pendulum are numbered by a wheel or escapement, having thirty teeth, which revolves once in a minute. Each tooth, therefore, answers to one vibration of the pendulum, and the wheel moves forward one tooth in a second, Thus the second-hand revolves once in every sixty beats of the pendulum; and, as these beats are seconds, it goes round once in a minute. By the pendulum the whole machine is regulated, for the clock goes faster or slower, according to its num-

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279. What is a pendulum? 280. What is meant by the vibration of a pendulum? What is that part of a circle called through which it swings? 281. Why does the pendulum vibrate in equal time whether it goes through a small or large part of its arc? 282. Describe the common clock. How many vibrations has the pendulum in a minute?

ber of vibrations in a given time. The number of vibrations which a pendulum makes in a given time depends upon its length, because a long pendulum does not perform its journey to and from the corresponding points of its arc so soon as a short one.

283. As the motion of the clock is regulated entirely by the pendulum, and as the number of vibrations are as its length, the least variation in this respect will alter its rate of going. To beat seconds, its length must be about thirty-nine inches. In the common clock, the length is regulated by a screw, which raises and lowers the weight. But as the rod to which the weight is attached is subject to variations of length, in consequence of the change of the seasons, being contracted by cold and lengthened by heat, the common clock goes faster in winter than in summer.

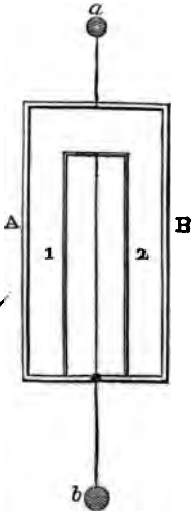
In the small clocks of the present day, the pendulum oscillates twice and sometimes more in a second, and consequently the escapement must have 60 or more teeth, the second-hand performing two revolutions in a minute.

The length of a pendulum beating two seconds is the square of that beating seconds. If the length of the seconds pendulum be 39¼ inches, then that beating two seconds will be about 13 feet.

A pendulum beating half seconds is in length, as the square root of that beating seconds, or about 10 inches long.

284. *Gridiron Pendulum.*—Various means have been contrived to counteract the effects of these changes, so that the pendulum may continue the same length the whole year. Among inventions for this purpose, the *gridiron* pendulum is considered among the best. It is so called, because it consists of several rods of different metals connected together at each end.

FIG. 45.



Gridiron Pendulum.

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283. On what depends the number of vibrations which a pendulum makes in a given time? What is the medium length of the pendulum beating seconds? Why does a common clock go faster in winter than in summer? What is necessary in respect to the pendulum, to make the clock go true the year round? 284. What is the principle on which the gridiron pendulum is constructed?

285. The principle on which this pendulum is constructed is derived from the fact that some metals dilate more by the same degrees of heat than others. Thus, brass will dilate about twice as much by heat, and, consequently, contract twice as much by cold, as steel. If, then, these differences could be made to counteract each other mutually, given points at each end of a system of such rods would remain stationary the year round, and thus the clock would go at the same rate in all climates, and during all seasons.

286. Suppose, then, steel bars A B, are firmly fixed to cross bars at each end, as seen by *Fig.* 45, and that on the lower cross bar, the brass rods 1 2, are also fixed, then the steel bars can expand only downward, and the brass ones, only upward. Now as the pendulum rod passes through the lower cross bar, and is fixed to the upper cross piece of the brass rods, it will be seen that the elongation of the two metals by heat mutually counteract each other, and therefore that the point of suspension, *a*, and the pendulum weight, *b*, will always remain at the same distance from each other. It is found by experiment that the expansion of brass to that of steel is in the proportion of 100 to 61.

287. *Gravity varies the Vibrations.*—As it is the force of gravity which draws the weight of the pendulum from the highest point of its arc downward, and as this force increases or diminishes as bodies approach toward the center of the earth, or recede from it, so the pendulum will vibrate faster or slower in proportion as this attraction is stronger or weaker.

288. Now it is known that the earth at the equator rises higher from its center than it does at the poles, for toward the poles it is flattened. The pendulum, therefore, being more strongly attracted at the poles than at the equator, vibrates more rapidly. For this reason, a clock that would keep exact time at the equator would gain time at the poles, for the rate at which a clock goes depends on the number of vibrations its pendulum makes. Therefore, pendulums, in order to beat seconds, must be shorter at the equator, and longer at the poles.

For the same reason, a clock which keeps exact time at the foot of a high mountain, would move slower on its top.

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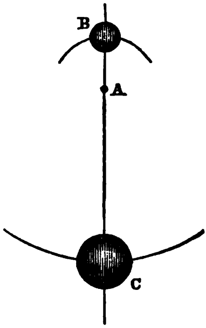
285. What are the metals of which this instrument is made? 286. Explain Fig. 45, and give the reason why the length of the pendulum will not change by the variations of temperature. 287. What is the downward force which makes the pendulum vibrate? Explain the reason why the same clock would go faster at the poles, and slower at the equator. 288. How can a clock which goes true at the equator be made to go true at the poles? Will a clock keep equal time at the foot and on the top of a high mountain? Why will it not?

289. **Metronome.**—There is a short pendulum, used by musicians for marking time, which may be made to vibrate fast or slow, as occasion requires. This little instrument is called a *metronome*, and besides the pendulum, consists of several wheels, and a spiral spring, by which the whole is moved. This pendulum is only ten or twelve inches long, and instead of being suspended by the end, like other pendulums, the rod is prolonged above the point of suspension, and there is a ball placed near the upper, as well as at the lower extremity.

290. This arrangement will be understood by *Fig.* 46, where A is the axis of suspension, B the upper ball, and C the lower one. Now, when this pendulum vibrates from the point A, the upper ball constantly retards the motion of the lower one, by in part counterbalancing its weight, and thus preventing its full velocity downward.

FIG. 46.



291. Perhaps this will be more apparent, by placing the pendulum, *Fig.* 47, for a moment on its side, and across a bar, at the point of suspension. In this position, it will be seen that the little ball would prevent the large one from falling with its full weight, since, were it moved to a certain distance from the point of suspension, it would balance the large one so that it would not descend at all. It is plain, therefore, that the comparative velocity of the large ball will be in proportion as the small one is moved to a greater or less distance from the point of suspension. The metronome is so constructed, the little ball being made to move up and down on the rod at pleasure, that its vibrations are made to beat the time of a quick or slow tune, as occasion requires.

FIG. 47.

Metronome.

By this arrangement, the instrument is made to vibrate every two seconds, or every half, or quarter of a second, at pleasure. *Metronome* means *time measurer.*

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289. What is the metronome? How does this pendulum differ from the common pendulums? 290. Explain Fig. 46. 291. How does the upper ball retard the motion of the lower one? How is the metronome made to go faster or slower, at pleasure?

CHAPTER IV.

MECHANICS.

292. *Mechanics is a science which investigates the laws and effects of force and motion.*

293. The practical object of this science is, to teach the best modes of overcoming resistances by means of mechanical powers, and to apply motion to useful purposes, by means of machinery.

294. A *machine* is any instrument by which power, motion, or velocity, is applied or regulated.

295. A machine may be very simple, or exceedingly complex. Thus, a pin is a machine for fastening clothes, and a steam-engine is a machine for propelling mills and boats.

As machines are constructed for a vast variety of purposes, their forms, powers, and kinds of movement, must depend on their intended uses.

Several considerations ought to precede the actual construction of a new or untried machine; for if it does not answer the purpose intended, it is commonly a total loss to the builder.

Many a man, on attempting to apply an old principle to a new purpose, or to invent a new machine for an old purpose, has been sorely disappointed, having found, when too late, that his time and money had been thrown away, for want of proper reflection, or requisite knowledge.

If a man, for instance, thinks of constructing a machine for raising a ship, he ought to take into consideration the *inertia* or *weight*, to be moved—the *force* to be applied—the *strength* of the materials, and the *space* or situation he has to work in. For, if the force applied, or the strength of the materials be insufficient, his machine is obviously useless; and if the force and strength be ample, but the space be wanting, the same result must follow.

If he intends his machine for twisting the fibers of flexible substances into threads, he may find no difficulty in respect to power, strength of materials, or space to work in, but if the

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292. What is mechanics? 293. What is the object of this science? 294. What is a machine? 295. Mention one of the most simple, and one of the most complex of machines.

velocity, *direction*, and kind of motion he obtains, be not applicable to the work intended, he still loses his labor.

Thousands of machines have been constructed, which, so far as regarded the skill of the workmen, the ingenuity of the contriver, and the construction of the individual parts, were models of art and beauty; and, so far as could be seen without trial, admirably adapted to the intended purpose. But on putting them to actual use, it has too often been found, that their only imperfection consisted in a stubborn refusal to do any part of the work intended.

Now, a thorough knowledge of the laws of motion, and the principles of mechanics, would, in many instances, at least, have prevented all this loss of labor and money, and spared him so much vexation and chagrin, by showing the projector that his machine would not answer the intended purpose.

The importance of this kind of knowledge is therefore obvious, and it is hoped will become more so as we proceed.

DEFINITIONS.

296. In mechanics, as well as in other sciences, there are words which must be explained, either because they are common words used in a peculiar sense, or because they are terms of art, not in common use. All technical terms will be as much as possible avoided, but still there are a few, which it is necessary here to explain.

297. *Force* is the means by which bodies are set in motion, kept in motion, and when moving, are brought to rest. The force of gunpowder sets the ball in motion, and keeps it moving, until the force of the resisting air, and the force of gravity, bring it to rest.

298. *Power* is the means by which the machine is moved, and the force gained. Thus we have horse-power, water-power, and the power of weights.

299. *Weight* is the resistance, or the thing to be moved by the force of the power. Thus the stone is the weight to be moved by the force of the lever or bar.

300. *Fulcrum*, or prop, is the point on which a thing is supported, and about which it has more or less motion. In raising a stone, the thing on which the lever rests, is the fulcrum.

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297. What is meant by force in mechanics? 298. What is meant by power? 299. What is understood by weight? 300. What is the fulcrum? 301. Are the mechanical powers numerous, or only few in number?

301. In mechanics, there are a few simple machines called the *mechanical powers*, and however mixed, or complex, a combination of machinery may be, it consists only of these few individual powers.

We shall not here burden the memory of the pupil with the names of these powers, of the nature of which he is at present supposed to know nothing, but shall explain the action and use of each in its turn, and then sum up the whole for his accommodation.

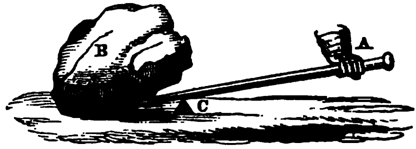
THE LEVER.

302. *Any rod, or bar, which is used in raising a weight, or surmounting a resistance, by being placed on a fulcrum, or prop, becomes a lever. Levers are simple and compound.*

303. *Simple levers* are of three kinds, namely: first, where the fulcrum is between the power and the weight; second, where the weight is between the fulcrum and the power; third, where the power is between the fulcrum and the weight.

304. *First Kind.*—The first kind is represented by *Fig.* 48, being a straight rod of iron, called a *crowbar*, in common use for raising rocks and other heavy bodies. The stone, B, is the *weight*, A the *lever*, and C the *fulcrum*; the *power* being the hand of a man applied at A.

FIG. 48.



Simple Lever.

It will be observed, that by this arrangement the application of a small power may be used to overcome a great resistance.

305. The force to be obtained by the lever, depends on its length, together with the power applied, and the distance of the weight and power from the fulcrum.

306. Suppose, *Fig.* 49, that A is the lever, B the fulcrum, D the weight to be raised, and C the power. Let D be considered three times as heavy as C, and the fulcrum three times as far from C as it is from D; then the weight and power will exactly balance each other. Thus, if the bar be four feet long,

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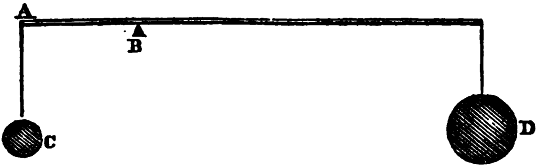
302. What is a lever? 303. What are the three kinds of simple levers? 304. What is the simplest of all mechanical powers? Explain Fig. 48. Which is the weight? Where is the fulcrum? Where is the power applied? What is the power in this case? 305. On what does the force to be obtained by the lever depend? 306. Suppose a lever four feet long, and the fulcrum one foot from the end, what number of pounds will balance each other at the ends?

FIG. 49.

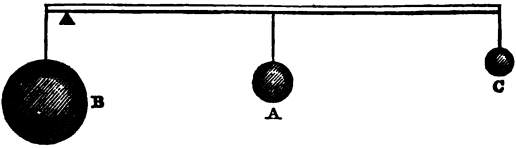


Lever—Unequal Arms.

and the fulcrum three feet from the end, then three pounds on the long arm will weigh just as much as nine pounds on the short arm, and these proportions will be found the same in all cases.

307. When two weights balance each other, the fulcrum is always at the center of gravity between them, and therefore, to make a small weight raise a large one, the fulcrum must be placed as near as possible to the large one, since the greater the distance *from the fulcrum the small weight* or power is placed, the greater will be its force.

FIG. 50.



Lever—Double Weights.

308. Suppose the weight B, *Fig.* 50, to be sixteen pounds, and suppose the fulcrum to be placed so near it, as to be raised by the power A, of four pounds hanging equally distant from the fulcrum and the end of the lever. If now the power A be removed, and another of two pounds, C, be placed at the end of the lever, its force will be just equal to A, placed at the middle of the lever.

309. But let the fulcrum be moved along to the middle of the lever, with the weight of sixteen pounds still suspended to it, it would then take another weight of sixteen pounds, instead of two pounds, to balance it, *Fig.* 51.

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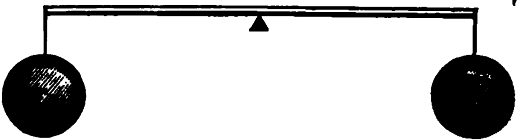
307. When weights balance each other, at what point between them must the fulcrum be? 308. Suppose a weight of 16 pounds on the short arm of a lever is counterbalanced by 4 pounds in the middle of the long arm, what power would balance this weight at the end of the lever? 309. Suppose the fulcrum to be moved to the middle of the lever, what power would then be equal to 16 pounds?

FIG. 51.



Lever—Equal Arms.

Thus, the power which would balance sixteen pounds, when the fulcrum is in one place, must be exchanged for another power weighing eight times as much, when the fulcrum is in another place.

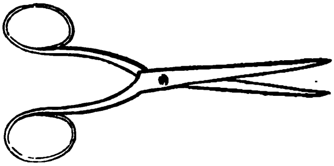
310. From these investigations, we may draw the following general truth, or proposition, concerning the lever: "*That the force of the lever increases in proportion to the distance of the power from the fulcrum, and diminishes in proportion as the distance of the weight from the fulcrum increases.*"

311. From this proposition, may be drawn the following rule, by which the exact proportions between the weight or resistance, and the power, may be found. *Multiply the weight by its distance from the fulcrum; then multiply the power by its distance from the same point, and if the products are equal, the weight and the power will balance each other.*

312. Suppose a weight of 100 pounds on the short arm of a lever, 8 inches from the fulcrum, then another weight, or power, of 8 pounds, would be equal to this, at the distance of 100 inches from the fulcrum; because 8 multiplied by 100 is equal to 800; and 100 multiplied by 8 is equal to 800, and thus they would mutually counteract each other.

313. Many instruments in common use are on the principle of this kind of lever. Scissors, *Fig.* 52, consist of two levers, the rivet being the *fulcrum* for both. The fingers are the *power*, and the cloth to be cut, the *resistance* to be overcome.

FIG. 52.



Two Levers.

Pincers, *forceps*, and *sugar-cutters*, are examples of this kind of lever.

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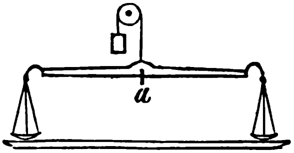
310. What is the general proposition drawn from these results? 311. What is the rule for finding the proportions between the weight and power? 312. Give an illustration of this rule. 313. What instruments operate on the principle of this lever?

314. A common *scale-beam*, used for weighing, is a lever, suspended at the center of gravity, so that the two arms balance each other. Hence the machine is called a *balance.* The fulcrum, or what is called the *pivot*, is sharpened, like a wedge, and made of hardened steel, so as much as possible to avoid friction.

FIG. 53.

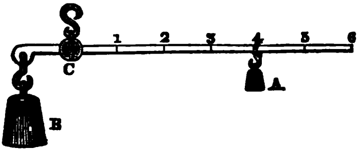


Common Scales.

315. A dish is suspended by cords to each end or arm of the lever, for the purpose of holding the articles to be weighed. When the whole is suspended at the point *a*, *Fig.* 53, the beam or lever ought to remain in a horizontal position, one of its ends being exactly as high as the other. If the weights in the two dishes are equal, and the support exactly in the center, they will always hang as represented in the figure.

316. A very slight variation of the point of support toward one end of the lever, will make a difference in the weights employed to balance each other. In weighing a pound of sugar, with a scale-beam of eight inches long, if the point of support is half an inch too near the weight, the buyer would be cheated nearly one ounce, and consequently nearly one pound in every sixteen pounds. This fraud might instantly be detected by changing the places of the sugar and weight, for then the difference would be quite material, since the sugar would then seem to want twice as much additional weight as it did really want.

FIG. 54.



Steelyard.

317. The *steelyard* differs from the balance, in having its support near one end, instead of in the middle, and also in having the weights suspended by hooks, instead of being placed in a dish.

If we suppose the beam to be 7 inches long, and the hook, C, *Fig.* 54, to be one inch from the end, then the pound weight, A, will require an additional pound at B, for every inch it is

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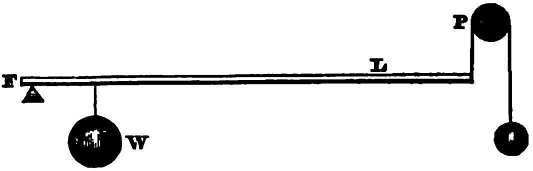
314. In the common scale-beam, where is the fulcrum? 315. In what position ought the scale-beam to hang? 316. How may a fraudulent scale-beam be made? How may the cheat be detected? 317. How does the steelyard differ from the balance?

moved from it. This, however, supposes that the bar will balance itself, before any weights are attached to it.

FIG. 55.



Lever of the Second Kind.

318. *Second Kind.*—The second kind of lever is represented by *Fig.* 55, where W is the weight, L the lever, F the fulcrum, and P a pulley, over which a string is thrown, and a weight suspended, as the power. In the common use of a lever of the first kind, the force is gained by bearing down the long arm, which is called *prying.* In the second kind, the force is gained by carrying the long arm in a contrary direction, or upward, and this is called *lifting.*

319. Levers of the second kind are not so common as the first, but are frequently used for certain purposes. The oars of a boat are examples of the second kind. The water against which the blade of the oar pushes, is the fulcrum, the boat is the weight to be moved, and the hands of the man, the power.

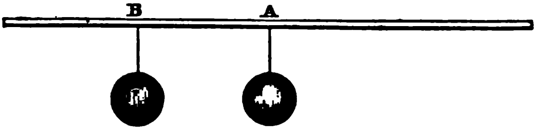
320. Two men carrying a load between them on a pole, is also an example of this kind of lever. Each man acts as the power in moving the weight, and at the same time each becomes the fulcrum in respect to the other.

If the weight happens to slide on the pole, the man toward whom it goes has to bear more of it in proportion as its distance from him is less than before.

321. A load at A, *Fig.* 56, is borne equally by the two men, being equally distant from each other; but at B, three quarters of its weight would be on the man at that end, because three quarters of the length of the lever would be on the side of the other man.

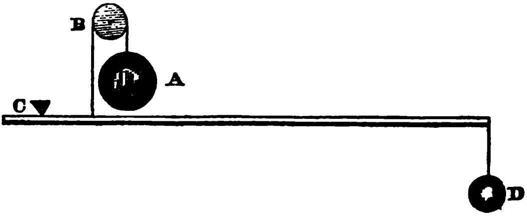
In the first kind of lever, where is the fulcrum, in respect to the weight and
In the second kind, where is the fulcrum, in respect to the weight and
What is the action of the first kind called? What is the action of the se-
called? 319. Give examples of the second kind of lever. 320. In rowing a
is the fulcrum, what the weight, and what the power? 321. What other
of this principle are given?

FIG. 56.



Lever—Unequal Arms.

FIG. 57



Lever of the Third Kind.

322. *Third Kind.*—In the third and last kind of lever, the weight is placed at one end, the fulcrum at the other end, and the power between them, or the hand, is between the fulcrum and the weight.

This is represented by *Fig.* 57, where C is the fulcrum, A the power, suspended over the pulley B, and D is the weight to be raised.

323. This kind of lever works to great disadvantage, since the power must be greater than the weight. It is therefore seldom used, except in cases where velocity and not force is required. In raising a ladder from the ground to the roof of a house, men are obliged sometimes to make use of this principle, and the great difficulty of doing so, illustrates the mechanical disadvantage of this kind of lever.

We have now described the three kinds of levers, and, we hope, have made the manner in which each kind acts plain, by illustrations. But to make the difference between them still more obvious, and to avoid all confusion, we will here compare them together.

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322. In the third kind of lever where are the respective places of the weight, power, and fulcrum? 323. What is the disadvantage of this kind of lever? Give an example of the use of the third kind of lever?

FIG. 58.

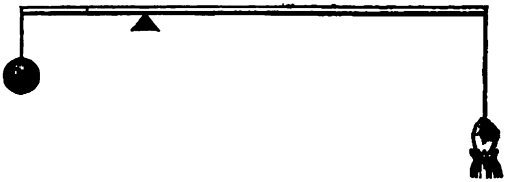


FIG. 59.

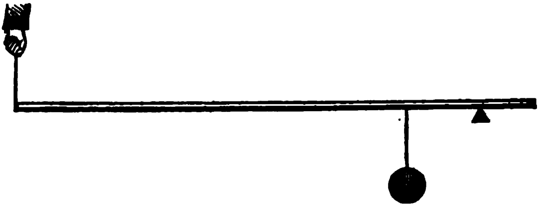
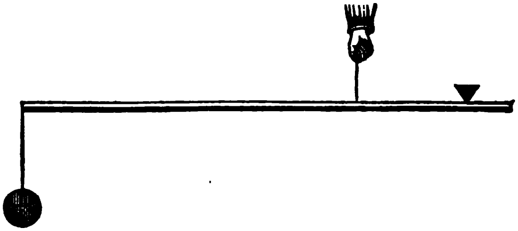


FIG. 60.



The Levers Compared.

324. In *Fig.* 58, the weight and hand both act downward. In 59, the weight and hand act in contrary directions, the hand upward and the weight downward, the weight being between them. In 60, the hand and weight also act in contrary directions, but the hand is between the fulcrum and the weight.

325. Compound Lever.—When several simple levers are connected together, and act one upon the other, the machine is

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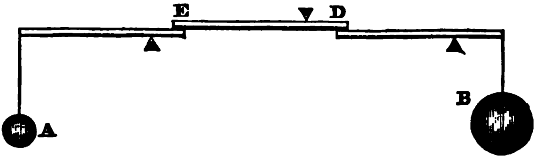
324. In what direction do the hand and weight act, in the first kind of lever? In what direction do they act in the second kind? In what direction do they act in the third kind? 325. What is a compound lever?

called a *compound lever*. In this machine, as each lever acts as an individual, and with a force equal to the action of the next lever upon it, the force is increased or diminished, and becomes greater or less, in proportion to the number or kind of levers employed.

We will illustrate this kind of lever by a single example, but must refer the inquisitive student to more extended works for a full investigation of the subject.

FIG. 61.



Compound Lever.

Fig. 61 represents a compound lever, consisting of three simple levers of the first kind.

326. In calculating the force of this lever, the rule applies which has already been given for the simple lever, namely: *The length of the long arm is to be multiplied by the moving power, and that of the short one, by the weight, or resistance.*

327. Let us suppose, then, that the three levers in the figure are of the same length, the long arms being six inches, and the short ones two inches long; required, the weight which a moving power of 1 pound at A will balance at B. In the first place, 1 pound at A, would balance 3 pounds at E, for the *lever* being 6 inches, and the power 1 pound, $6 \times 1 = 6$, and the short one being 2 inches, $2 \times 3 = 6$. The long arm of the second lever being also 6 inches, and moved with a power of 3 pounds, multiply the 3 by $6 = 18$; and multiply the length of the short arm, being 2 inches, by $9 = 18$. These two products being equal, the power upon the long arm of the third lever, at D, would be 9 pounds. 9 pounds $\times 6 = 54$, and 27×2, is 54; so that 1 pound at A would balance 27 at B.

The increase of force is thus slow, because the proportion between the long and short arms is only as 2 to 6, or in the proportions of 1, 3, 9.

---

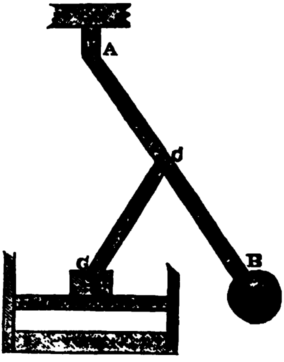
326. By what rule is the force of the compound lever calculated? 327. How many pounds weight will be raised by three levers connected, of six inches each, with the fulcrum two inches from the end, by a power of one pound?

328. Now suppose the long arms of these levers to be 18 inches, and the short ones 1 inch, and the result will be surprisingly different, for then 1 pound at A would balance 18 pounds at E, and the second lever would have a power of 18 pounds. This being multiplied by the length of the lever, 18×18=324 pounds at D. The third lever would thus be moved by a power of 324 pounds, which, multiplied by 18 inches for the weight it would raise, would give 5832 pounds.

329. The compound lever is employed in the construction of *weighing machines*, and particularly in cases where great weights are to be determined, in situations where other machines would be inconvenient, on account of their occupying too much space.

330. KNEE LEVER.—A compound instrument, called the *Knee Lever*, is used in various kinds of machinery, the principle of which is explained by *Fig.* 62.

FIG. 62.



Knee Lever.

This combination consists of a metal rod, A B, having a joint at A, above which there is a firm support. At C is another rod, or bar, jointed to the long lever, and terminating at G, where there is another joint, attached to a movable platform, on which the force of the two levers are exerted.

Now when B is pushed toward the vertical position, the force on the joints A and G, is constantly increased, until the two bars become perpendicular, when the pressure exerted, is augmented to nearly an indefinite degree.

331. Various engines for pressing paper, and for printing, are constructed on this principle, and it is said they are unequaled in power, except by the Hydrostatic press.

WHEEL AND AXLE.

332. The mechanical power, next to the lever in arrange-

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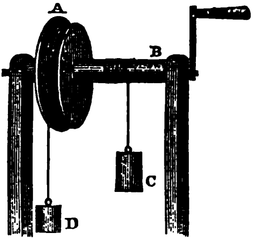
328. If the long arms of the levers be eighteen inches, and the short ones one inch, how much will a power of one pound balance? 329. In what machines is the compound lever employed? 330. Explain the principle of the Knee Lever, Fig 62. 331 What machines are on this principle?

ment, is the *wheel and axle.* It is, however, much more complex than the lever.

333. It consists of two wheels, one of which is larger than the other, but the small one passes through the larger, and hence both have a common center, on which they turn.

FIG. 63.

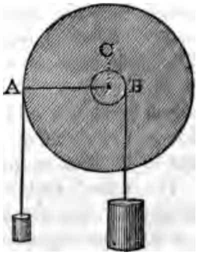


Wheel and Axle.

334. The manner in which this machine acts will be understood by *Fig.* 63. The large wheel, A, on turning the machine, will take up, or throw off, as much more rope than the small wheel or axle, B, as its circumference is greater. If we suppose the circumference of the large wheel to be four times that of the small one, then it will take up the rope four times as fast. And because A is four times as large as B, 1 pound at D will balance 4 pounds at C, on the opposite side.

335. The principle of this machine is that of the lever, as will be apparent by an examination of *Fig.* 64.

FIG. 64.



Wheel and Axle.

336. This figure represents the machine endwise, so as to show in what manner the lever operates. The two weights hanging in opposition to each other, the one on the wheel at A, and the other on the axle at B, act in the same manner as if they were connected by the horizontal lever A B, passing from one to the other, having the common center, C, as a fulcrum between them.

337. The wheel and axle, therefore, acts like a constant succession of levers, the long arm being half the diameter of the wheel, and the short one half the diameter of the axle; the common center of both being the fulcrum. The wheel and axle has, therefore, been called the *perpetual* lever.

338. The great advantage of this mechanical arrangement is, that while a single lever of the same power can raise a weight

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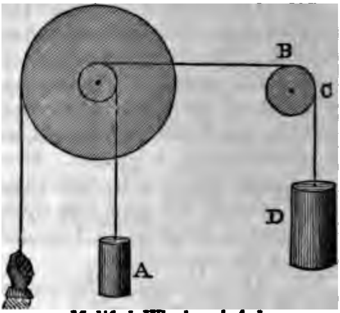
332. What is the next mechanical power to the lever? 333. Describe this machine. 334. Explain Fig. 63. 335. On what principle does this machine act? 336. In Fig. 64, which is the fulcrum, and which the two arms of the lever? 337. What is this machine called, in reference to the principle on which it acts? 338. What is the great advantage of this machine over the lever and other mechanical powers?

but a few inches at a time, and then only in a certain direction, this machine exerts a continual force, and in any direction wanted. To change the direction, it is only necessary that the rope by which the weight is to be raised, should be carried in a line perpendicular to the axis of the machine, to the place below where the weight lies, and there be let fall over a pulley.

FIG. 65.

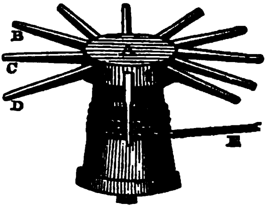


Modified Wheel and Axle.

339. Suppose the wheel and axle, *Fig.* 65, is erected in the third story of a store-house, with the axle over the scuttles, or doors through the floors, so that goods can be raised by it from the ground-floor, in the direction of the weight A. Suppose, also, that the same store stands on a wharf, where ships come up to its side, and goods are to be removed from the vessels into the upper stories. Instead of removing the goods into the store, and hoisting them in the direction of A, it is only necessary to carry the rope B, over the pulley C, which is at the end of a strong beam projecting out from the side of the store, and then the goods will be raised in the direction of B, thus saving the labor of moving them twice.

The wheel and axle, under different forms, is applied to a variety of common purposes.

FIG. 66.



Capstan.

340. The *capstan*, in universal use, on board of ships, is an axle placed upright, with a head, or drum, A, *Fig.* 66, pierced with holes for the levers B, C, D. The weight is drawn by the rope, E, passing two or three times round the axle to prevent its slipping.

341. This is a very powerful and convenient machine. When not in use, the levers are taken out

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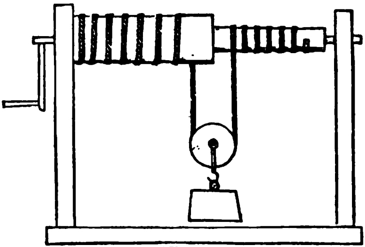
339. Describe Fig. 65, and point out the manner in which weights can be raised by letting fall a rope over the pulley. 340. What is the capstan? Where is it chiefly used? 341. What are the peculiar advantages of this form of the wheel and axle?

of their places and laid aside, and when great force is required, two or three men can push at each lever.

342. WINDLASS.—The *common windlass* for drawing water is another modification of the wheel and axle. The *winch*, or *crank*, by which it is turned, is moved around by the hand, and there is no difference in the principle, whether a whole wheel is turned, or a single spoke. The winch, therefore, answers to the wheel, while the rope is taken up, and the weight raised by the axle, as already described.

FIG. 67.



Windlass.

In cases where great weights are to be raised, and it is required that the machine should be as small as possible, on account of room, the simple wheel and axle, modified as represented by *Fig.* 67, is sometimes used.

343. The axle may be considered in two parts, one of which is larger than the other. The rope is attached by its two ends, to the ends of the axle, as seen in the figure. The weight to be raised is attached to a small pulley, around which the rope passes. The elevation of the weight may be thus described. Upon turning the axle, the rope is coiled around the larger part, and, at the same time, it is thrown off the smaller part. At every revolution, therefore, a portion of the rope will be drawn up, equal to the circumference of the thicker part, and at the same time a portion, equal to that of the thinner part, will be let down. On the whole, then, one revolution of the machine will shorten the rope where the weight is suspended, just as much as the difference is between the circumference of the two parts.

344. *Illustration.*—Now to understand the principle on which this machine acts, we must refer to *Fig.* 68, where it is obvious that the two parts of the rope, A and B, equally support the weight D, and that the rope, as the machine turns, passes from the small part of the axle E to the large part H, consequently,

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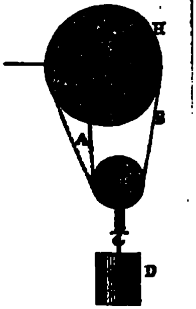
342. In the common windlass, what part answers to the wheel? Explain Fig. 67. 343. Why is the rope shortened, and the weight raised? 344. What is the design of Fig. 68? Does the weight rise perpendicular to the axis of motion?

FIG. 68.



Windlass.

the weight does not rise in a perpendicular line toward C, the center of both, but in a line between the outsides of the large and small parts.

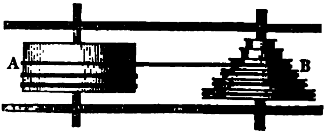
345. Let us consider what would be the consequence of changing the rope A to the larger part of the axle, so as to place the weight in a line perpendicular to the axis of motion. In this case, it is obvious that the machine would be in equilibrium, since the weight D would be divided between the two sides equally, and the two arms of the lever passing through the center C, would be of equal length, and therefore no advantage would be gained.

346. But in the actual arrangement, the weight being sustained equally by the large and small parts, there is involved a lever power, the long arm of which is equal to half the diameter of the large part, while the short arm is equal to half the diameter of the small part, the fulcrum being between them.

A Varying Power, producing a Constant Force.—If a power, varying under any given conditions, be required to overcome a resistance which varies according to some other given conditions, the one may be accommodated to the other by producing a variation in the leverage, by which one or both acts.

347. This is done in the mechanism of the watch, of, which A, *Fig.* 69, is the *barrel* containing the power in the form of a convoluted spring, and B the *fusee* which acts as a varying lever, and through which motion is conveyed to the hands of the watch.

FIG. 69.



Barrel and Fusee.

348. Now when the watch is first wound up, the main-spring within the barrel is closely coiled, and of course acts with much more power than afterward, when it is partly unrolled; hence, were no means used to equalize this power, every watch would

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345. Suppose the cylinder was, throughout, of the same size, what would be the consequence? 346. On what principle does this machine act? Which are the long and short arms of the lever, and where is the fulcrum? 347. What is the main spring of a watch? 348. Where is it contained? What is the fusee of a watch? What is its form? When does the main spring act with most force?

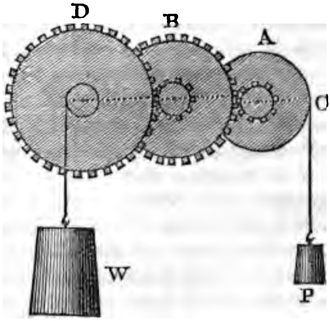
run two or three times as fast, when first wound up, as afterward.

349. We shall see that the fusee is a complete remedy for the varying action of the main-spring. Its form is a low cone, with its surface cut into a spiral groove, to receive the chain, which runs round the barrel. Now when the watch is wound up, by applying the key to the axis of the fusee at C, the main-spring, one end of which is attached to the diameter of the barrel, and the other to its axis, is closely coiled; but as the action begins on the smallest part of the fusee, the leverage is short, and the power weak; but as the fusee turns, and the spring uncoils, the leverage increases in proportion as the strength of the spring becomes weaker, and thus the two forces mutually equalize each other, and the watch runs at the same rate until the chain which connects them has run from the barrel to the fusee, when it again requires winding, and the same process begins again.

350. System of Wheels.—*As the wheel and axle is only a modification of the simple lever, so a system of wheels acting on each other, and transmitting the power to the resistance, is only another form of the compound lever.*

351. Such a combination is shown in *Fig.* 70. The first wheel, A, by means of the teeth, or cogs, around its axle, moves the second wheel, B, with a force equal to that of a lever, the long arm of which extends from the center to the circumference of the wheel, where the power P is suspended, and the short arm from the same center to the ends of the cogs. The dotted line C, passing through the center of the wheel A, shows the position of the lever, as the wheel now stands. The center on which the wheel and axle turns, is the fulcrum of this lever. As the wheel turns, the short arm

FIG. 70.



System of Wheels.

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349. How does the fusee equalize this force? Explain how the forces of the spring and fusee mutually equalize each other. 350. On what principle does a system of wheels act, as represented in Fig. 70? 351. Explain Fig. 70, and show how the power P is transferred by the action of levers?

of this lever will act upon the long arm of the next lever by means of the teeth on the circumference of the wheel B, and this again through the teeth on the axle of B, will transmit its force to the circumference of the wheel D, and so by the short arm of the third lever to the weight W. As the power or small weight falls, therefore, the resistance W, is raised, with the multiplied force of three levers acting on each other.

352. In respect to the force to be gained by such a machine, suppose the number of teeth on the axle of the wheel A to be six times less than the number of those on the circumference of the wheel B, then B would only turn round once, while A turns six times. And, in like manner, if the number of teeth on the circumference of D, be six times greater than those on the axle of B, then D would turn once, while B is turned six times. Thus six revolutions of A would make B revolve once, and six revolutions of B would make D revolve once. Therefore, A makes thirty-six revolutions while D makes only one.

353. The diameter of the wheel A, being three times the diameter of the axle of the wheel D, and its velocity of motion being 36 to 1, 3 times 36 will give the weight which a power of 1 pound at P would raise at W. Thus $36 \times 3 = 108$. One pound at P would therefore balance 108 pounds at W.

354. NO MACHINE CREATES FORCE.—If the student has attended closely to what has been said on mechanics, he will now be prepared to understand, that no machine, however simple or complex, can *create* the least degree of force. It is true, that one man with a machine may apply a force which a hundred could not exert with their hands, but then it would take him a hundred times as long.

355. Suppose there are 20 blocks of stone to be moved a hundred feet; perhaps twenty men, by taking each a block, would move them all in a minute. One man, with a capstan, we will suppose, may move them all at once, but this man, with his lever, would have to make one revolution for every foot he drew the whole load toward him, and therefore to make one hundred revolutions to perform the whole work. It will also take him twenty times as long to do it, as it took the twenty men. His task, indeed, would be more than twenty times harder than that performed by the twenty men, for, in addition to moving the stone, he would have the friction of the machinery

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353. What weight will one pound at P balance at W? 354. Is there any actual power gained by the use of machinery? 355. Suppose twenty men to move twenty stones to a certain distance with their hands, and one man moves them back to the same place with a capstan, which performs the most actual labor? Why?

to overcome, which commonly amounts to nearly one third of the force employed.

356. Hence there would be an actual loss of power by the use of the capstan, though it might be a convenience for the one man to do his work by its means, rather than to call in nineteen of his neighbors to assist him.

357. Any power by which a machine is moved, must be equal to the resistance to be overcome, and, in all cases where the power descends, there will be a proportion between the velocity with which it moves downward, and the velocity with which the weight moves upward.

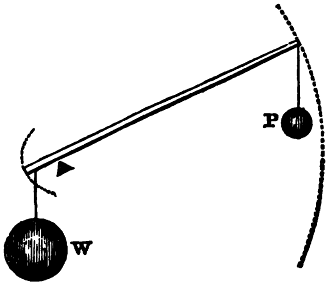
358. There will be no difference in this respect, whether the machine be simple or compound, for if its force be increased by increasing the number of levers, or wheels, the velocity of the moving power must also be increased, as that of the resistance is diminished.

359. There being, then, always a proportion between the velocity with which the moving force descends, and that with which the weight ascends, whatever this proportion may be, it is necessary that the power should have to the resistance the same ratio that the velocity of the resistance has to the velocity of the power. In other words, "*The power multiplied by the space through which it moves, in a vertical direction, must be equal to the weight multiplied by the space through which it moves in a vertical direction.*"

This law is known under the name of "the law of virtual velocities," and is considered the *golden rule* of mechanics.

360. This principle has already been explained, while treating of the lever, (312;) but that the student should want nothing to assist him in clearly comprehending so important a law, we will again illustrate it in a different manner.

FIG. 71.



Weight and Space.

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356. Why, then, is machinery a convenience? 357 In the use of the lever, what proportion is there between the force of the short arm, and the velocity of the long arm? Is it said, that the velocity of the power downward, must be in proportion to that of the weight upward? 358. Does it make any difference, in this respect, whether the machine be simple or compound? 359. What is the golden rule of mechanics? Explain Fig. 71, and show how the rule is illustrated by it.

Suppose the lever, *Fig.* 71, to be thirty inches long from the fulcrum to the point where the power, P, is suspended, and that the weight, W, is two inches from the fulcrum. If the power be 1 pound, the weight must be 15 pounds, to produce equilibrium, and the power, P, must fall thirty inches to raise the weight, W, two inches. Therefore, the power being 1 pound, and the space 30 inches, 30 × 1 = 30. The weight being 15 pounds, and the space 2 inches, 15 × 2 = 30.

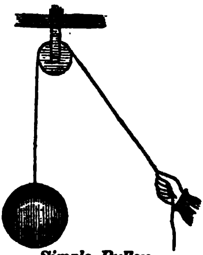
Thus, the power multiplied by the space through which it falls, and the weight multiplied by the space through which it rises, are equal.

361. However complex the machine may be, by which the force of a descending power is transmitted to the weight to be raised, the same rule will apply as it does to the action of the simple lever.

THE PULLEY.

362. *A pulley consists of a wheel which is grooved on the edge, and which is made to turn on its axis, by a cord passing over it.*

FIG. 72.



Simple Pulley.

363. *Simple Pulley.*—*Fig.* 72, represents a *simple pulley*, with a single fixed wheel. In other forms of the machine, the wheel moves up and down with the weight.

364. The pulley is arranged among the simple mechanical powers; but when several are connected, the machine is called a *system of pulleys*, or a *compound pulley.*

365. One of the most obvious advantages, of the pulley is, its enabling men to exert their own power in places where they can not go themselves. Thus, by means of a rope and wheel, a man can stand on the deck of a ship, and hoist a weight to the topmast.

366. By means of two fixed pulleys, a weight may be raised upward, while the power moves in a horizontal direction. The weight will also rise vertically through the same space that the rope is drawn horizontally.

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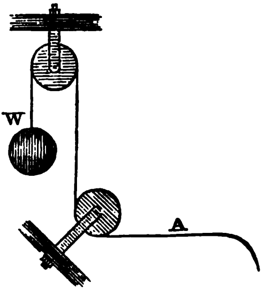
361. What is said of the application of this rule to complex machines? 362. What 's a pulley? 363. What is a simple pulley? 364. What is a system of pulleys, or a npound pulley? 365. What is the most obvious advantage of the pulley? 366. w must two fixed pulleys be placed to raise a weight vertically as far as the ver goes horizontally?

FIG. 73.



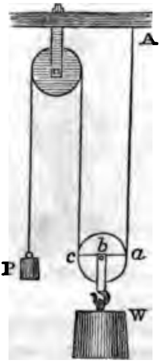
Simple Pulley.

Fig. 73, represents two fixed pulleys, as they are arranged for such a purpose. In the erection of a lofty edifice, suppose the upper pulley to be suspended to some part of the building; then a horse pulling at the rope, A, would raise the weight, W, vertically, as far as he went horizontally.

367. In the use of the *wheel* of the pulley, there is no mechanical advantage, except that which arises from removing the friction, and diminishing the imperfect flexibility of the rope.

In the mechanical effects of this machine, the result would be the same did it slide on a smooth surface with the same ease that its motion makes the wheel revolve.

FIG. 74.



Movable Pulley.

368. The action of the pulley is on a different principle from that of the wheel and axle. A system of wheels, as already explained, acts on the same principle as the compound lever. But the mechanical efficacy of a system of pulleys is derived entirely from the division of the weight among the strings employed in suspending it.

369. In the use of the single *fixed* pulley, there can be no mechanical advantage, since the weight rises as fast as the power descends. This is obvious by *Fig.* 74, where it is also apparent that the power and weight must be equal, to balance each other, as already shown.

In the single movable pulley, *Fig.* 74, the same rope passes from the fixed point, A, to the power, P. It is evident here, that the weight is supported equally by the two parts of the string between which it hangs. Therefore, if we call the weight, W, ten pounds, five pounds will be supported by one string, and five by the other. The power, then, will support twice its own weight; so that a per-

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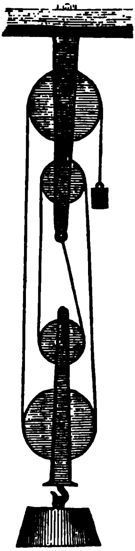
367. What is the advantage of the wheel of the pulley? 368. How does the action of the pulley differ from that of the wheel and axle? 369. Is there any mechanical advantage in the fixed pulley? What weight at P, Fig. 74, will balance ten pounds at W?

son pulling with a force of five pounds at P, will raise ten pounds at W. The mechanical force, therefore, in respect to the power, is as two to one.

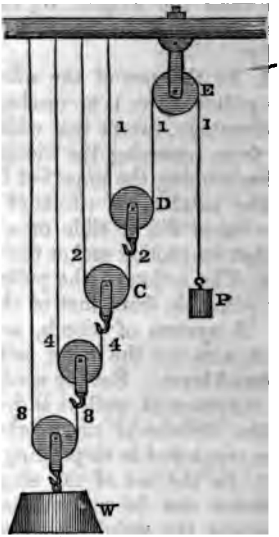
In this example, it is supposed there are only two ropes, each of which bears an equal part of the weight.

FIG. 75.



Compound Pulley.

FIG. 76.



System of Pulleys.

370. *Compound Pulley.*—If the number of ropes be increased, the weight may be increased with the same power; or the power may be diminished in proportion as the number of ropes is increased. In *Fig.* 75, the number of ropes sustaining the weight is four, and therefore, the weight may be four times as great as the power. This principle must be evident, since it is plain that each rope sustains an equal part of the weight. The weight may, therefore, be considered as divided into four parts, and each part sustained by one rope.

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370. Suppose the number of ropes be increased, and the weight increased, must the power be increased also? Suppose the weight, Fig. 75, to be thirty-two pounds, what will each rope bear?

371. In *Fig.* 76, there is a system of pulleys represented, in which the weight is sixteen times the power.

The tension of the rope, D E, is evidently equal to the power, P, because it sustains it. D, being a movable pulley, must sustain a weight equal to twice the power; but the weight which it sustains, is the tension of the second rope, D C. Hence, the tension of the second rope is twice that of the first; and, in like manner, the tension of the third rope is twice that of the second, and so on, the weight being equal to twice the tension of the last rope.

372. Suppose the weight, W, to be sixteen pounds; then the two ropes, 8 and 8, would sustain 8 pounds each, this being the whole weight divided equally between them. The next two ropes, 4 and 4, would evidently sustain but half this whole weight, because the other half is already sustained by a rope fixed at its upper end. The next two ropes sustain but half of 4, for the same reason; and the next pair, 1 and 1, for the same reason, will sustain only half of 2. Lastly, the power, P, will balance two pounds, because it sustains but half this weight, the other half being sustained by the same rope, fixed at its upper end.

It is evident that, in this system, each rope and pulley which is added will double the effect of the whole. Thus, by adding another rope and pulley beyond 8, the weight, W, might be 32 pounds, instead of 16, and still be balanced by the same power.

373. In our calculations of the effects of pulleys, we have allowed nothing for the weight of the pulleys themselves, or for the friction of the ropes. In practice, however, it will be found that nearly one-third must be allowed for friction, and that the power, therefore, to actually raise the weight must be about one-third greater than has been allowed.

374. The pulley, like other machines, obeys the laws of virtual velocities, already applied to the lever and wheel. *Thus, "in a system of pulleys, the ascent of the weight, or resistance, is as much less than the descent of the power as the weight is greater than the power."* If, as in the last example, the weight is 16 pounds, and the power 1 pound, the weight will rise only 1 foot, while the power descends 16 feet.

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371. Explain Fig. 76, and show what part of the weight each rope sustains, and why one pound at P, will balance sixteen pounds at W. 372. Explain the reason why each additional rope and pulley will double the effect of the whole, or why its weight may be double that of all the others with the same power. 373. In compound machines, how much of the power must be allowed for the friction? 374. What general law applies to the pulley?

375. In the single fixed pulley, the weight and power are equal, and, consequently, the weight rises as fast as the power descends.

With such a pulley, a man may raise himself up to the masthead by his own weight. Suppose a rope is thrown over a pulley, and a man ties one end of it round his body, and takes the other end in his hands; he may raise himself up, because, by pulling with his hands, he has the power of throwing more of his weight on that side than on the other, and when he does this, his body will rise. Thus, although the power and the weight are the same individual, still the man can change his center of gravity so as to make the power greater than the weight, or the weight greater than the power, and thus can elevate one half of his weight in succession.

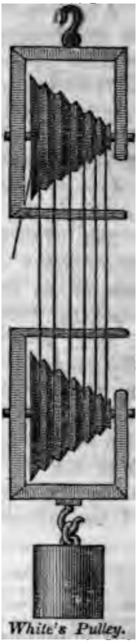
WHITE'S PULLEY.

376. In all the pulleys we have described, there is a great defect, in consequence of the different velocities at which the several wheels turn, and the consequent friction to which some of them are subjected.

377. It has been an object among mechanical philosophers, to remedy this defect by inventing a system of pulleys, the wheels of which should all revolve on their axles in the same time, each making the same number of revolutions, notwithstanding the different lengths of rope passing over them, and thus avoid a defect common to those in use.

378. This object seems to have been fully attained by Mr. James White, whose invention is represented by *Fig.* 77, and which will be understood by the following description. In order that the successive wheels should revolve in the same time, and their circumferences should be just equal to the length of rope passing over them, Mr. White made them all of different diameters. By this construction, although the length of rope passing over each was different, yet their revolutions are equal, both with respect to time and number.

FIG. 77.



White's Pulley.

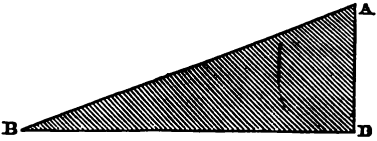
By this arrangement all the friction is

avoided, except that of a pivot at each end, and the lateral friction of a single wheel. A single rope sustains the whole, and as in other systems, the weight is as many times the power as there are ropes sustaining the lower block. This is considered the most perfect system of pulleys yet invented.

THE INCLINED PLANE.

379. *This power, the most simple of all machines, consists of a hard, smooth plane, inclined to the horizon in various degrees.* It is the fourth mechanical power, and is represented by *Fig.* 78, where from A to B is the *inclined plane;* the line from D to A, is its height, and that from B to D, its base.

FIG. 78.



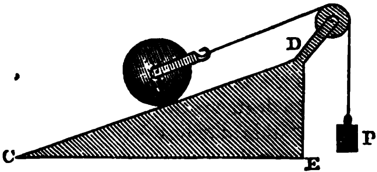
Inclined Plane.

A board with one end on the ground, and the other resting on a block, becomes an inclined plane.

380. This machine being both useful and easily constructed, is in very general use, especially where heavy bodies are to be raised only to a small height. Thus a man, by means of an inclined plane, which he can readily construct with a board, or couple of bars, can raise a load into his wagon, which ten men could not lift with their hands.

381. *The power required to force a given weight up an inclined plane, is in proportion to its height, and the length of its base, or, in other words, the force must be in proportion to the rapidity of its inclination.*

FIG. 79.



Inc'ined Plane.

382. The power, P, *Fig.* 79, pulling a weight up the inclined plane, from C to D, only raises it in an oblique direction from E to D, by acting along the whole length of the plane. If the

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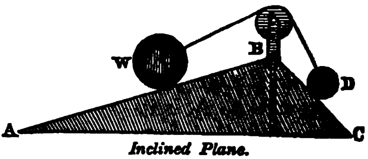
375. How may a man raise himself up by means of a rope and single fixed pulley? 376. What is a great defect in the common pulley? 377. In what manner is it said that the defect with respect to friction might be remedied? 378. Describe White's pulley, and show how the defects in other pulleys are remedied by this. 379. What is an inclined plane? 380. On what occasions is this power chiefly used? Suppose a man wants to put a barrel of cider into his wagon, how does he make an inclined plane for this purpose?

plane be twice as long as it is high, that is, if the line from C to D be double the length of that from E to D, then one pound at P will balance two pounds any where between D and C. It is evident, by a glance at this figure, that were the base lengthened, the height from E to D being the same, a less power at P would balance an equal weight any where on the inclined plane; and so, on the contrary, were the base made shorter, that is, the plane more steep, the power must be increased in proportion.

383. Suppose two inclined planes, *Fig.* 80, of the same height, with bases of different lengths; then the weight and power will be to each other as the length of the planes. If the length from A to B is two feet, and that from B to C one foot, then two pounds at D will balance four pounds at W, and so in this proportion, whether the planes be longer or shorter.

FIG. 80.

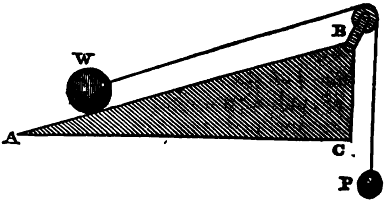


Inclined Plane.

384. The same principle, with respect to the virtual velocities of the weight and power, applies to the inclined plane, in common with the other mechanical powers.

Suppose the inclined plane, *Fig.* 81, to be two feet from A to B, and one foot from C to B, then, as we have already seen by *Fig.* 79, a power of one pound at P, would balance a weight of two pounds at W. Now, in the fall of the power to draw up the weight, it is obvious that its vertical descent must be just twice the vertical ascent of the weight; for

FIG. 81.



Inclined Plane.

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381. To roll a given weight up an inclined plane, to what must the force be proportioned? 382. Explain Fig. 79. 383. If the length of the long plane, Fig. 80, be double that of the short one, what must be the proportion between the power and the weight? 384. What is said of the application of the law of virtual velocities to the inclined plane? Explain Fig. 81, and show why the power must fall twice as far as the weight rises.

the power must fall down the distance from A to B, to draw the weight that distance; but the vertical height to which the weight W is raised, is only from C to B. Thus the power, being two pounds, must fall two feet, to raise the weight, four pounds, one foot; and thus the power and weight, multiplied by their several velocities, are equal.

When the power of an inclined plane is considered as a machine, it must therefore be estimated by the proportion which the length bears to the height; *the power being increased in proportion as the elevation of the plane is diminished.*

385. APPLICATION TO ROADS.—Hilly roads may be regarded as inclined planes, and loads drawn upon them in carriages, considered in reference to the powers which draw them, are subject to all the conditions which we have stated, with respect to inclined planes.

The power required to draw a load up a hill, is in proportion to the elevation of the inclined plane. On a road perfectly horizontal, if the power is sufficient to overcome the friction, and the resistance of the atmosphere, the carriage will move. But if the road rise one foot in fifteen, besides these impediments, the moving power will have to lift one fifteenth part of the load.

386. Now, where is there a section of country in which the traveler is not vexed with roads, passing straight over hills, when precisely the same distance would carry him around them on a level plane? To use a homely, but very pertinent illustration, "the bale of a pot is no longer, when it lies down, than when it stands up." Had this simple fact been noticed, and its practical bearing carried into effect by road makers, many a high hill would have been shunned for a circuit around its base, and many a poor horse, could he speak, would thank the wisdom of such a decision.

THE WEDGE.

387. *The next simple mechanical power is the wedge. This instrument may be considered as two inclined planes, placed base to base.*

It is much employed for the purpose of splitting or dividing solid bodies, such as wood and stone.

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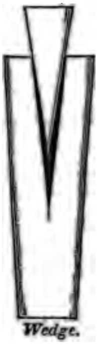
385. How do the principles of the inclined plane apply to roads? 386. What is said about the bale of a pot, as applied to road making? 387. On what principle does the wedge act? In what case is this power useful?

FIG. 82.



Wedge.

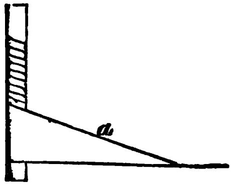
388. *Fig.* 82 represents such a wedge as is usually employed in cleaving timber. This instrument is also used in raising ships, and preparing them to launch, and for a variety of other purposes. Nails, awls, needles, and many cutting instruments, act, more or less, on the principle of this machine.

389. There is much difficulty in estimating the power of the wedge, since this depends on the force, or the number of blows given it, together with the obliquity of its sides. A wedge of great obliquity would require hard blows to drive it forward, for the same reason that a plane, much inclined, requires much force to roll a heavy body up it. But were the obliquity of the wedge, and the force of each blow given, still it would be difficult to ascertain the exact power of the wedge in ordinary cases, for, in the splitting of timber and stone, for instance, the divided parts act as levers, and thus greatly increase the power of the wedge. Thus, in a log of wood, six feet long, when split one half of its length, the other half is divided with ease, because the two parts act as levers, the lengths of which constantly increase, as the cleft extends from the wedge.

THE SCREW.

390. *The screw is the sixth and last simple mechanical power. It may be considered as a modification of the inclined plane, or as a winding wedge.*

FIG. 83.



Winding Wedge.

391. It is an inclined plane running spirally round a spindle, as will be seen by *Fig.* 83. Suppose *a* to be a piece of paper, cut into the form of an inclined plane and rolled round the piece of wood *d*; its edge would form the spiral line, called the *thread* of the screw. If the finger be placed between the two threads of a screw, and the screw be turned round once, the finger will be raised upward equal to the distance of the two

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388. What common instruments act on the principle of the wedge? 389. What difficulty is there in estimating the power of the wedge? 390. On what principle does the screw act? 391. How is it shown that the screw is a modification of the inclined plane?

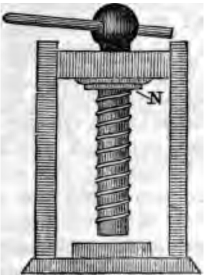
threads apart. In this manner, the finger is raised up the inclined plane, as it runs round the cylinder.

The power of the screw is transmitted and employed by means of another screw called the *nut*, through which it passes. This has a spiral groove running through it, which exactly fits the thread of the screw.

If the nut is fixed, the screw itself, on turning it round, advances forward; but if the screw is fixed, the nut, when turned, advances along the screw.

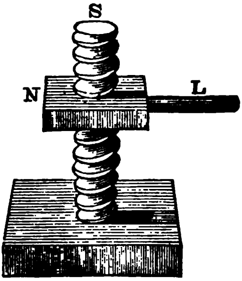
392. *Fig.* 84 represents the first kind of screw, being such as is commonly used in pressing paper, and other substances. The nut, N, through which the screw passes, answers also for one of the beams of the press. If the screw be turned to the right, it will advance downward, while the nut stands still.

FIG. 84.



Nut Fixed.

FIG. 85.



Screw Fixed.

393. A screw of the second kind is represented by *Fig.* 85. In this, the screw is fixed, while the nut, N, by being turned by the lever, L, from right to left, will advance down the screw.

394. In practice, the screw is never used as a simple mechanical machine; the power being always applied by means of a lever, passing through the head of the screw, as in *Fig.* 84, or into the nut, as in *Fig.* 85.

395. POWER OF THE SCREW.—*The screw acts with the combined power of the inclined plane and the lever, and its force is*

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392. Explain Fig. 84. Which is the screw, and which the nut? Which way must the screw be turned to make it advance through the nut? 393. How does the screw, Fig. 84, differ from Fig. 85? 394. Is the screw ever used as a simple machine? By what simple power is it moved? 395. What two simple mechanical powers are concerned in the force of the screw?

such as to be limited only by the strength of the materials of which it is made.

In investigating the effects of this machine, we must, therefore, take into account both these simple mechanical powers, so that the screw now becomes really a compound engine.

396. In the inclined plane, we have already seen, that the less it is inclined, the more easy is the ascent up it. In applying the same principle to the screw, it is obvious, that the greater the distance of the threads from each other, the more rapid the inclination, and consequently, the greater must be the power to turn it, under a given weight. On the contrary, if the thread inclines but slightly, it will turn with less power, for the same reason that a man can roll a heavy weight up a plane but little inclined. Therefore, the finer the screw, or the nearer the threads to each other, the greater will be the pressure under a given power.

397. Let us suppose two screws, the one having the threads one inch apart, and the other half an inch apart; then the force which the first screw will give with the same power at the lever, will be only half that given by the second. The second screw must be turned twice as many times round as the first, to go through the same space; but what is lost in velocity is gained in power. At the lever of the first, two men would raise a given weight to a given height, by making one revolution; while at the lever of the second, one man would raise the same weight to the same height, by making two revolutions.

398. It is apparent that the length of the inclined plane, up which a body moves in one revolution, is the circumference of the screw, and its height the interval between the threads. The proportion of its power would therefore be "*as the circumference of the screw, to the distance between the threads, so is the weight to the power.*"

399. By this rule the power of the screw alone can be found; but as this machine is moved by means of the lever, we must estimate its force by the combined power of both. In this case, the circumference described by the end of the lever employed, is taken, instead of the circumference of the screw itself. The means by which the force of the screw may be found, is therefore, by multiplying the circumference which the lever describes by the power.

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396. Why does the nearness of the threads make a difference in the force of the screw? 397. Suppose one screw, with its threads one inch apart, and another half an inch apart, what will be their difference in force? 398. What is the length of the inclined plane, up which a body moves by one revolution of the screw?

400. Thus, "*the power multiplied by the circumference which it describes, is equal to the weight or resistance, multiplied by the distance between the two contiguous threads.*" Hence the efficacy of the screw may be increased, by increasing the length of the lever, or by diminishing the distance between the threads. If, then, we know the length of the lever, the distance between the threads, and the weight to be raised, we can readily calculate the power; or, the power being given, and the distance of the threads and the length of the lever known, we can estimate the weight the screw will raise.

401. Thus, suppose the length of the lever to be forty inches, the distance of the threads one inch, and the weight 8000 pounds; required, the power, at the end of the lever, to raise the weight.

The lever being 40 inches, the diameter of the circle, which the end describes, is 80 inches. The circumference is a little more than three times the diameter, but we will call it just three times. Then, $80 \times 3 = 240$ inches, the circumference of the circle. The distance of the threads is 1 inch, and the weight 8000 pounds. To find the power, multiply the weight by the distance of the threads, and divide by the circumference of the circle. Thus,

Circum.		In.		Weight.		Power.
240	:	1	: :	8000	:	33⅓

The power at the end of the lever must therefore be 33⅓ pounds. In practice, this power would require to be increased about one-third, on account of friction.

402. PERPETUAL SCREW.—*The force of the screw is sometimes employed to turn a wheel, by acting on its teeth. In this case it is called the perpetual screw.*

403. *Fig.* 86 represents such a machine. It is apparent, that by turning the crank C, the wheel will revolve, for the thread of the screw passes between the cogs of the wheel. By means of an axle, through the center of this wheel, like the common wheel and axle, this becomes an exceedingly powerful machine, but like all other contrivances for obtaining great power, its effective motion is exceedingly slow. It has, however, some disadvantages, and particularly the great friction be-

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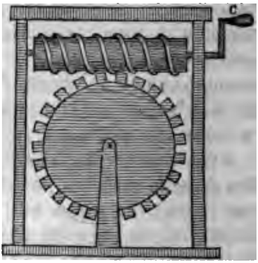
400. How is the force of the screw estimated? How may the efficacy of the screw be increased? 401. The length of the lever, the distance between the threads, and the weight being known, how can the power be found? Give an example. 402. What is the screw called when it is employed to turn a wheel? 403. Explain Fig. 86. What is the objection to this machine for raising weights?

tween the thread of the screw and the teeth of the wheel, which prevents it from being generally employed to raise weights.

FIG. 86.



Screw and Wheel.

404. All these Mechanical Powers resolved into Three.—We have now enumerated and described all the mechanical powers usually denominated simple. They are six in number, namely, the Lever, Wheel and Axle, Pulley, Wedge, Inclined Plane, and Screw.

405. In respect to the principles on which they act, they may be resolved into three simple powers, namely, the lever, the inclined plane, and the pulley; for it has been shown that the wheel and axle is only another form of the lever, and that the screw is but a modification of the inclined plane.

It is surprising, indeed, that these simple powers can be so arranged and modified, as to produce the different actions in all that vast variety of intricate machinery which men have invented and constructed.

406. Card Machine.—The variety of motions we witness in the little engine which makes cards, by being supplied with wire for the teeth, and strips of leather to stick them through, would itself seem to involve more mechanical powers than those enumerated. This engine takes the wire from a reel; bends it into the form of teeth; cuts it off; makes two holes in the leather for the tooth to pass through; sticks it through; then gives it another bend on the opposite side of the leather; graduates the spaces between the rows of teeth, and between one tooth and another; and, at the same time, carries the leather backward and forward, before the point where the teeth are introduced, with a motion so exactly corresponding with the motions of the parts which make and stick the teeth, as not to produce the difference of a hair's breadth in the distance between them.

All this is done without the aid of human hands, any further than to put the leather in its place, and turn a crank; or, in some instances, many of these machines are turned at once, by means of three or four dogs, walking on an inclined plane which revolves.

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404. How many simple mechanical powers are there, and what are they called? 405. How can they be resolved into three simple powers? 406. What is said of the card-making machine?

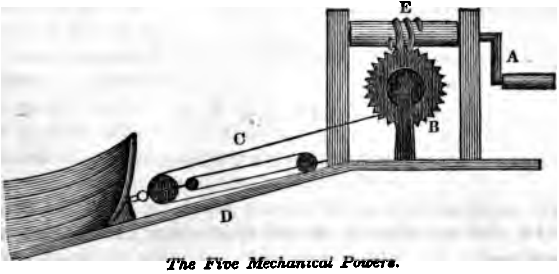
407. Such a machine displays the wonderful ingenuity and perseverance of man, and at first sight would seem to set at naught the idea that the lever and wheel are the chief simple powers concerned in its motions. But when these motions are examined singly and deliberately, we are soon convinced that the wheel variously modified, is the principal mechanical power in the whole engine.

408. USE OF MACHINERY.—It has already been stated, (354,) that notwithstanding the vast deal of time and ingenuity which men have spent on the construction of machinery, and in attempting to multiply their powers, there has, as yet, been none produced, in which the power was not obtained at the expense of velocity, or velocity at the expense of power; and, therefore, no actual force is ever generated by machinery.

When men employ the natural elements as a power to overcome resistance by means of machinery, there is a vast saving of animal labor. Thus mills, and all kinds of engines, which are kept in motion by the power of water, or wind, or steam, save animal labor equal to the power it takes to keep them in motion.

409. *Five Mechanical Powers in one Machine.*—An engineer, it is said, for the purpose of drawing a ship out of the water to be repaired, combined the mechanical powers represented by *Fig.* 87, and perhaps no machine ever constructed gives greater force with so small a power.

FIG. 87.



The Five Mechanical Powers.

It involves the lever A, wheel and axle B, the pulley C, the inclined plane D, and the screw E.

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407. What are the chief mechanical powers concerned in its motions? 408. Is there any actual force generated by machinery? What is said of employing the natural elements as a power? 409. What are the five mechanical powers employed in Fig. 87? Point out on the cut the place of each power.

To estimate the force of this engine, it is necessary to know the length of the lever, diameter of the wheel, &c.

Suppose then, the sizes of the different powers are as follows, viz.:—

Length of the lever A,	18 inches.
Distance of the thread E,	1 inch.
Diameter of the wheel B,	4 feet.
Diameter of the axle,	1 foot.
Pulleys C and D, D fixed,	4 strings.
Height of the plane D, one-half its length,	2 feet.

Suppose the man turns the lever A, with the power equal to 100 pounds, the force on the ship would thus be found, for the different laws and rules referring to each mechanical power.

	Pounds.
1. One hundred pounds on the lever A, would become a force by means of the screw on the wheel B of.	11,309.76
2. Diameter of wheel four times that of the axle,	4
	45,239.04
3. The number of pulley strings,	4
	180,956.16
4. Height of the inclined plane half its lenth,	2
	361,912.32

The force on the ship therefore would be equal to 361,912 pounds, or about 161 tons.

CHAPTER V.

HYDROSTATICS.

410. *Hydrostatics is the science which treats of the weight, pressure, and equilibrium of water, or other fluids, when in a state of rest.*

411. *Hydraulics* is that part of the science of fluids which treats of water in motion, and the means of raising and conducting it in pipes, or otherwise, for all sorts of purposes.

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409. What must be known to estimate the power of this machine? What is the amount of force on the ship? 410. What is hydrostatics? 411. How does hydraulics differ from hydrostatics?

The subject of water at rest, will first claim investigation, since the laws which regulate its motion will be best understood by first comprehending those which regulate its pressure.

412. *A fluid is a substance whose particles are easily moved among each other, as air and water.*

413. The air is called an *elastic* fluid, because it is easily compressed into a smaller bulk, and returns again to its original state when the pressure is removed. Water is called a *non-elastic* fluid, because it admits of little diminution of bulk under pressure.

414. The non-elastic fluids are perhaps more properly called *liquids*, but both terms are employed to signify water and other bodies possessing its mechanical properties. The term *fluid*, when applied to the air, has the word *elastic* before it.

415. One of the most obvious properties of fluids, is the facility with which they yield to the impressions of other bodies, and the rapidity with which they recover their former state, when the pressure is removed. The cause of this, is the freedom with which their particles slide over, or among each other; their cohesive attraction being so slight as to be overcome by the least impression. On this want of cohesion among their particles seems to depend the peculiar mechanical properties of these bodies.

416. In solids, there is such a connection between the particles, that if one part moves, the other part must move also. But in fluids, one portion of the mass may be in motion, while the other is at rest. In solids, the pressure is always downward, or toward the center of the earth's gravity; but in fluids, the particles seem to act on each other as wedges, and hence, when confined, the pressure is sideways, and even upward, as well as downward.

417. *Elasticity of Water.*—Water has commonly been called a non-elastic substance, but it is found that under great pressure its volume is slightly diminished, and hence it is proved to be elastic. The most decisive experiments on this subject were made many years ago by Mr. Perkins.

418. These experiments were made by means of a hollow cylinder, *Fig.* 88, which was closed at the bottom, and made water-tight at the top, by a cap, screwed on. Through this

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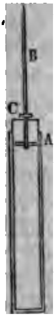
412. What is a fluid? 413 What is an elastic fluid? Why is air called an elastic fluid? 414. What substances are called liquids? 415. What is one of the most obvious properties of liquids? 416. On what do the peculiar mechanical properties of fluids depend? In what respect does the pressure of a fluid differ from that of a solid? 417. Is water an elastic, or a non-elastic fluid? 418. Describe Fig. 88, and show how water was found to be elastic.

cap, at A, passed the rod B, which was five-sixteenths of an inch in diameter. The rod was so nicely fitted to the cap, as also to be water-tight. Around the rod at C, there was placed a flexible ring, which could be easily pushed up or down, but fitted so closely as to remain on any part where it was placed.

FIG. 88.



Water Elastic.

A cannon of sufficient size to receive this cylinder, which was three inches in diameter, was furnished with a strong cap and forcing pump, and set vertically into the ground. The cannon and cylinder were next filled with water, and the cylinder, with its rod drawn out, and the ring placed down to the cap, as in the figure, was plunged into the cannon. The water in the cannon was then subjected to an immense pressure by means of the forcing pump, after which, on examination of the apparatus, it was found that the ring C, instead of being where it was placed, was eight inches up the rod. The water in the cylinder being compressed into a smaller space, by the pressure of that in the cannon, the rod was driven in, while under pressure, but was forced out again by the expansion of the water, when the pressure was removed. Thus, the ring on the rod would indicate the distance to which it had been forced in, during the greatest pressure.

419. This experiment proved that water, under the pressure of one thousand atmospheres, that is, the weight of 15,000 pounds to the square inch, was reduced in bulk about one part in 24.

So slight a degree of elasticity under such immense pressure, is not appreciable under ordinary circumstance, and therefore in practice, or in common experiments on this fluid, water is considered as non-elastic.

EQUAL PRESSURE OF WATER.

420. *The particles of water, and other fluids, when confined, press on the vessel which confines them, in all directions, both upward, downward, and sideways.*

From this property of fluids, together with their weight, very unexpected and surprising effects are produced.

The effect of this property, which we shall first examine, is,

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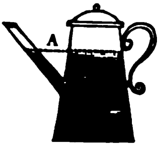
419. In what proportion does the bulk of water diminish under a pressure of 15,000 pounds to the square inch? In common experiments, is water considered elastic, or non-elastic? 420. When water is confined, in what direction does it press?

that a quantity of water, however small, will balance another quantity, however large. Such a proposition at first thought might seem very improbable. But on examination, we shall find that an experiment with a very simple apparatus will convince any one of its truth. Indeed, we every day see this principle established by actual experiment, as will be seen directly.

421. *Fig.* 89, represents a common coffee-pot, supposed to be filled up to the dotted line A, with a decoction of coffee, or any other liquid. The coffee, we know, stands exactly at the same height, both in the body of the pot, and in its spout. Therefore, *the small quantity in the spout, balances the large quantity in the pot, or presses with the same force downward, as that in the body of the pot presses upward.* This is obviously true, otherwise, the large quantity would sink below the dotted line, while that in the spout would rise above it, and run over.

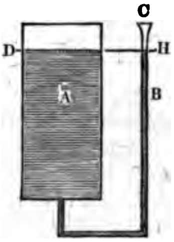
FIG. 89.



Coffee-Pot.

422. The same principle is more strikingly illustrated by *Fig.* 90.

FIG. 90.



Pressure of Water.

Suppose the cistern A to be capable of holding one hundred gallons, and into its bottom there be fitted the tube B, bent, as seen in the figure, and capable of containing one gallon. The top of the cistern, and that of the tube, being open, pour water into the tube at C, and it will rise up through the perpendicular bend into the cistern, and if the process be continued, the cistern will be filled by pouring water into the tube. Now it is plain, that the gallon of water in the tube presses against the hundred gallons in the cistern, with a force equal to the pressure of the hundred gallons, otherwise, that in the tube would be forced upward higher than that in the cistern, whereas, we find that the surfaces of both stand exactly at the same height.

423. From these experiments we learn, "*that the pressure of a fluid is not in proportion to its quantity, but to its height,*

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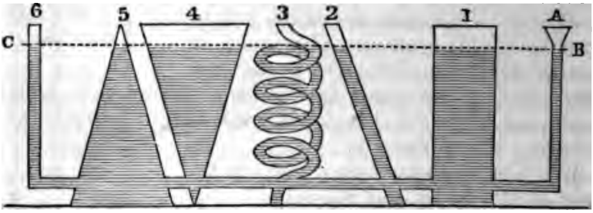
421. How does the experiment with the coffee-pot show that a small quantity of liquid will balance a large one? 422. Explain Fig. 90, and show how the pressure in the tube is equal to the pressure in the cistern. 423. What conclusion, or general truth, is to be drawn from these experiments?

and that a large quantity of water in an open vessel, press with no more force than a small quantity of the same height."

424. ***Pressure equal in Vessels of all Sizes and Shapes.***— The size or shape of a vessel is of no consequence, for if a number of vessels, differing entirely from each other in figure, position, and capacity, have a communication made between them, and one be filled with water, the surface of the fluid, in all, will be at the same elevation. If, therefore, the water stands at an equal height in all, the pressure in one must be just equal to that in another, and so equal to that in all the others.

FIG. 91.



Equal Pressure of Water.

425. To make this obvious, suppose a number of vessels, of different shapes and sizes, as represented by *Fig.* 91, to have a communication between them, by means of a small tube, passing from the one to the other. If, now, one of these vessels be filled with water, or if water be poured into the tube A, all the other vessels will be filled at the same instant, up to the line B C. Therefore, the pressure of the water in A, balances that in 1, 2, 3, &c., while the pressure in each of these vessels is equal to that in the other, and so an equilibrium is produced throughout the whole series.

426. If an ounce of water be poured into the tube A, it will produce a pressure on the contents of all the other vessels, equal to the pressure of all the others on the tube: for, it will force the water in all the other vessels to rise upward to an equal height to that in the tube itself. Hence, we must conclude, that the pressure in each vessel is not only equal to that in any

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424. What difference does the shape or size of a vessel make in respect to the pressure of a fluid on its bottom? 425. Explain Fig. 91, and show how the equilibrium is produced. 426. Suppose an ounce of water be poured into the tube A, what will be its effect on the contents of the other vessels?

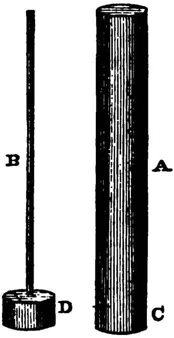
of the others, but also that the pressure in any one is equal to that in all the others.

427. From this, we learn that the shape or size of a vessel has no influence on the pressure of its liquid contents, but that the pressure of water is as its height, whether the quantity be great or small. We learn, also, that in no case will the weight of a quantity of liquid, however large, force another quantity, however small, above the level of its own surface.

428. Now, by other experiments, it is ascertained, *that the pressure of a liquid is in proportion to its height, and the area of its base.*

Suppose a vessel, ten feet high, and two feet in diameter, such as is represented at A, *Fig.* 92, to be filled with water; there would be a certain amount of pressure, at C, near the bottom. Let D represent another vessel, of the same diameter at the bottom, but only a foot high, and closed at the top. Now if a small tube, the fourth of an inch in diameter, be inserted into the cover of this vessel, and the tube be carried to the height of the vessel A, and then the vessel and tube be filled with water, the pressure on the bottoms and sides of both vessels at the same height will be equal, and jets of water starting from D and C will have exactly the same force, and spout to the same distance.

FIG. 92.



This might at first seem improbable, but to convince ourselves of its truth, we have only to consider, that any impression made on one portion of the confined fluid in the vessel D, is instantly communicated to the whole mass. Therefore, the water in the tube B, presses with the same force on every other portion of the water in D, as it does on that small portion over which it stands.

429. *Bursting a Cask.*—This principle is illustrated in a very striking manner, by the experiment, which has often been made, of bursting a common wine cask with a few ounces of water.

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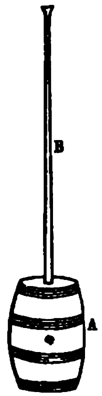
427. What conclusion is to be drawn from pouring the ounce of water into the tube A? What is the reason that a large quantity of water will not force a small quantity above its own level? Is the force of water in proportion to its height, or its quantity? 428 How is a small quantity of water shown to press equal to a large quantity, by Fig. 92? 429. Explain the reason why the pressure is as great at D, as at C.

Suppose A, *Fig.* 93, to be such a cask, already filled with water, and suppose the tube B, fifty feet high, to be screwed, water-tight, into its head. When water is poured into the tube, so as to fill it gradually, the cask will show increasing signs of pressure, by emitting the water through the pores of the wood, and between the joints; and, finally, as the tube is filled, the cask will burst asunder.

FIG. 93.



Bursting a Cask

430. The same apparatus will serve to illustrate the upward pressure of water; for, if a small stop-cock be fitted to the upper head, on turning this, when the tube is filled, a jet of water will spirt up with a force, and to a height, that will astonish all who never before saw such an experiment.

In theory, the water will spout to the same height with that which gives the pressure, but, in practice, it is found to fall short in the following proportions:—

431. If the tube be twenty feet high, and the orifice for the jet half an inch in diameter, the water will spout nearly nineteen feet. If the tube be fifty feet high, the jet will rise upward of forty feet, and if a hundred feet, it will rise above eighty feet. It is understood, in every case, that the tubes are to be kept full of water.

The height of these jets shows the astonishing effects that a small quantity of fluid produces when pressing from a perpendicular elevation.

432. Hydrostatic Paradox.—This paradox, illustrated by *Fig.* 94, consists in experimental proof of the principle already insisted on, that water presses according to its height, and not to its quantity. Fill a glass jar with water, and balance it on the scale-beam F, E, with small weights. Then pour out the water, leaving only an inch or two deep, letting the balance weights remain. Replacing the jar, which will now stand higher than before, owing to the loss of water, introduce into it, by means of the crane, H, a piece of wood a few lines smaller in all directions than the inside of the jar. The wood being

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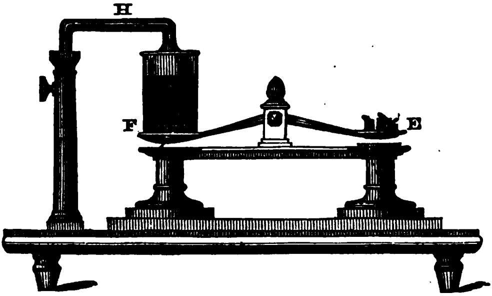
How is the same principle illustrated by Fig. 93? 430. How may Fig. 93 be made to illustrate the upward pressure of water? 431. Under the pressure of a column of water twenty feet high, what will be the height of the jet? Under a pressure of a hundred feet, how high will it rise? 432. What does the hydrostatic paradox show? Explain by the figure how the experiment is made.

FIG. 94.



Hydrostatic Paradox.

adjusted by means of the thumb-screw, so that the water is made to rise around it exactly to the brim, or as high as it stood before any was poured out, (the wood not touching the glass,) and it will be found that it will exactly balance the weights, as it did when full of water, though it now contains only a tenth as much as before.

The result will be the same if, instead of the wood, the same bulk of cork or lead be placed in the jar, the only point being, that, in each case, the water should rise to the same height.

The above experiment proves, in a very striking manner, that the pressure of water is as its height; and the reason why it makes no difference in the result whether the body placed in the jar be of wood, cork, or lead is, that the solid merely takes the place of the fluid, displacing its own bulk, and thus the weight remains just as though the water itself had remained in the jar. Thus, the pressure of a tenth part of the water, of equal height, equals the whole.

433. *Proof by Mercury.*—In addition to the above proofs, that a small, will balance a large quantity of water, we add the following, perhaps the most satisfactory of all.

Let A, B, C, *Fig.* 95, represent a glass tube, having at A, a collar cemented to the glass, into which vessels of different capacities and shapes, may be screwed. The tube is first filled with mercury up to the level of the dotted line A C, and the tube G *p*, fitted in its place. The vessel D, is then screwed into A, and water is poured in as far as *h*, the base of the column

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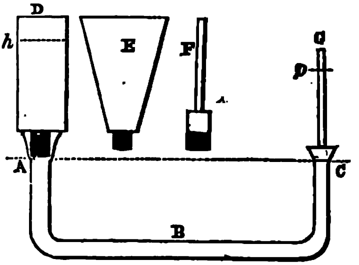
433. Explain Fig. 95, and show in what manner different quantities of water will balance the same weight of mercury.

FIG. 95.

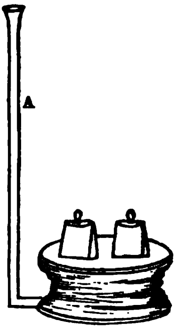


Proof by Mercury.

of water being, as seen, equal to that of the mercury. The fluid metal will rise, by the pressure of the water on A, up to *p* in the small tube. Then unscrew D, and in its place fix the conical vessel E, and pour in water as before, and the same result will follow, and so with the small tube F; in each case, the height of the water, notwithstanding the difference in quantity, will force the mercury to exactly the same elevation.

434. Hydrostatic Bellows.—An instrument called the hydrostatic bellows, also shows, in a striking manner, the great force of a small quantity of water, pressing in a perpendicular direction.

FIG. 96.



Hydrostatic Bellows.

This instrument consists of two boards, connected together with strong leather, in the manner of the common bellows. It is then furnished with a tube A, *Fig.* 96, which communicates between the two boards. A person standing on the upper board may raise himself up by pouring water into the tube. If the tube holds an ounce of water, and has an area equal to a thousandth part of the area of the top of the bellows, one ounce of water in the tube will balance a thousand ounces placed on the bellows.

435. Hydrostatic Press.—This property of water was applied by Mr. Bramah, to the construction of his *hydrostatic* press. But instead of a high tube of water, which in most cases could not be so readily obtained, he substituted a strong forcing-pump, and instead of the leather bellows, a metallic pump, barrel, and piston.

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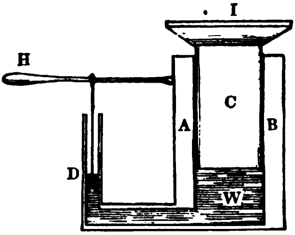
434. What is the hydrostatic bellows? What property of water is this instrument designed to show? 435. Explain Fig. 97. Where is the piston? Which is the pump-barrel in which it works?

FIG. 97.



Hydrostatic Press.

This arrangement will be understood by *Fig.* 97, where the pump-barrel, A, B, is represented as divided lengthwise, in order to show the inside. The piston, C, is fitted so accurately to the barrel, as to work up and down water-tight; both barrel and piston being made of iron. The thing to be broken or pressed, is laid on the flat surface, I, there being above this, a strong frame to meet the pressure, not shown in the figure. The small forcing-pump, of which D is the piston, and H, the lever by which it is worked, is also made of iron.

Now, suppose the space between the small piston and the large one, at W, to be filled with water, then, on forcing down the small piston, D, there will be a pressure against the large piston, C, the whole force of which will be in proportion as the aperture in which C works, is greater than that in which D works.

436. If the piston, D, is half an inch in diameter, and the piston, C, one foot in diameter, then the pressure on C will be 576 times greater than that on D. Therefore, if we suppose the pressure of the small piston to be one ton, the large piston will be forced up against any resistance, with a pressure equal to the weight of 576 tons.

437. It would be easy for a single man to give the pressure of a ton at D, by means of the lever, and, therefore, a man, with this engine, would be able to exert a force equal to the weight of near 600 tons.

438. It is evident that the force to be obtained by this principle, can only be limited by the strength of the materials of which the engine is made. Thus, if a pressure of two tons be given to a piston, the diameter of which is only a quarter of an inch, the force transmitted to the other piston, if three feet in diameter, would be upward of 40,000 tons; but such a force

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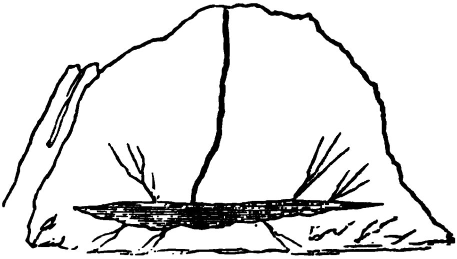
436. In the hydrostatic press, what is the proportion between the pressure given by the small piston, and the force exerted on the large one? 437. What is the estimated force which a man could give by one of these engines? 438. If the pressure of two tons be made on a piston of a quarter of an inch in diameter, what will be the force transmitted to the other piston of three feet in diameter?

is much too great for the strength of any material with which we are acquainted.

A small quantity of water, extending to a great elevation, would give the pressure above described, it being only for the sake of convenience, that the forcing-pump is employed instead of a column of water.

439. *Rupture of a Mountain.*—There is no doubt, but in the operations of nature, great effects are sometimes produced among mountains, by a small quantity of water finding its way to a reservoir in the crevices of the rocks far beneath.

FIG. 98.



Rupture of a Mountain.

Suppose, in the interior of a mountain, at A, *Fig.* 98, there should be a space of ten yards square, and an inch deep, filled with water, and closed up on all sides; and suppose that, in the course of time, a small fissure, no more than an inch in diameter, should be opened by the water, from the height of two hundred feet above, down to this little reservoir. The consequence might be, that the side of the mountain would burst asunder, for the pressure, under the circumstances supposed, would be equal to the weight of five thousand tons.

440. *Pressure on Vessels with Oblique Sides.*—It is obvious, that, in a vessel, the sides of which are every where perpendicular to each other, the pressure on the bottom will be as the height, and that the pressure on the sides will every where be equal, at an equal depth of the liquid.

But it is not so obvious, that in a vessel having oblique sides,

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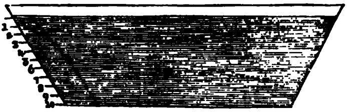
439. What is said of the pressure of water in the crevices of mountains and its effects? 440. What is the pressure on the bottom of a vessel containing a fluid equal to? Suppose the sides of the vessel slope outward, what effect does this produce on the pressure?

that is, diverging outward from the bottom, or converging from the bottom toward the top, in what manner the pressure will be sustained.

441. Now, the pressure on the bottom of any vessel, no matter what the shape may be, is equal to the height of the fluid, and the area of the bottom, (428.)

FIG. 99.



Pressure on Diverging Sides.

Hence the pressure on the bottom of the vessel sloping outward, *Fig.* 99, will be just equal to what it would be, were the sides perpendicular, and the same would be the case did the sides slope inward instead of outward.

In a vessel of this shape, the sides sustain a pressure equal to the perpendicular height of the fluid, above any given point. Thus, if the point 1 sustain a pressure of one pound, 2, being twice as far below the surface, will have a pressure equal to two pounds, and so in this proportion with respect to the other eight parts marked on the side of the vessel. On the contrary, did the sides of the vessel slope inward instead of outward, still the same consequences ensue, the vertical height in both cases making the pressure equal. For although in the latter, the elevation is not above the point of pressure, the effect is the same in each case.

PRESSURE OF WATER IN POUNDS, AT VARIOUS DEPTHS.

442. The weight of a cubic inch of water at the temperature of 62°, is the 0.036065 fraction of a pound. A column of water one foot high, being twelve times the above, would therefore be 0.4328 pounds.

443. Now a square foot is 144 square inches, and therefore the pressure, or weight, of a square foot of water will be found by multiplying the above fraction by 144, which gives 62.3232, or nearly 62 and a third pounds. Omitting the decimals, a cubic foot of water is commonly estimated at 62 pounds.

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441. On the contrary, did the sides of the vessel slope inward exactly the same amount of pressure according to the height, what would be the result? 442. What is the weight of a cubic inch of water? 443. What is the weight of a cubic foot of water?

The following table, founded on the above estimates, may be useful in determining the pressure of water in pipes or other vessels, of known depth.

DEPTH IN FEET.	PRESSURE PER SQUARE INCH.	PRESSURE PER SQUARE FOOT.
	Pounds.	Pounds.
1	0.4328	62.3232
2	0.8656	124.6464
3	1.2984	186,9696
4	1.7312	249.2928
5	2.1640	311.6160
6	2.5968	373.9392
7	3.0296	436.2624
8	3.4624	498.5856
9	3,8952	560.9088
10	4.3280	623.2320

Suppose it is required to know the pressure on the bottom of a vessel of water, 1 foot square and 20 feet deep, then it is found by doubling that of 10 feet deep, thus 623.2320 × 2 = 1246.464 pounds. The pressure on a tube equal to an inch square, and of an equal depth, is found by substituting inches for feet, as above seen.

WATER LEVEL.

444. We have seen, that in whatever situation water is placed, it always tends to seek a *level.* Thus, if several vessels communicating with each other be filled with water, the fluid will be at the same height in all, and the level will be indicated by a straight line drawn through all the vessels as in *Fig.* 91.

It is on the principle of this tendency that the little instrument called the *water level* is constructed.

445. Let A, *Fig.* 100, be a straight glass tube having two legs, or two other glass tubes rising from each end at right-angles. Let the tube A, and a part of the legs, be filled with mercury or some other liquid, and on the surfaces, *a b*, of the liquid, let floats be placed, carrying upright wires, to the ends of which are attached sights at 1, 2. These sights are represented by 3, 4, and consist of two fine threads, or hairs, stretched

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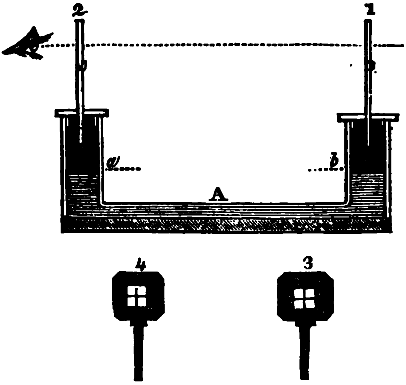
445. Explain by Fig. 100, how an exact line may be obtained by adjusting the sights.

FIG. 100.



Improved Water Level.

at right-angles across a square, and are placed at right-angles to the length of the instrument.

They are so adjusted that the point where the hairs intersect each other, shall be at equal heights above the floats. This adjustment may be made in the following manner:—

Let the eye be placed behind one of the sights, looking through it at the other, so as to make the points, where the hairs intersect, cover each other, and let some distant object, covered by this point, be observed. Then let the instrument be reversed, and let the points of intersection of the hairs be viewed in the same way, so as to cover each other. If they are observed to cover the same distant object as before, they will be of equal heights above the surfaces of the liquid. But, if the same distant points be not observed in the direction of these points, then one or the other of the sights must be raised or lowered, by an adjustment provided for that purpose, until the points of intersection be brought to correspond. The points will then be properly adjusted, and the line passing through them will be exactly horizontal. All points seen in the direction of the sights will be on the level of the instrument.

446. The principles on which this adjustment depends are easily explained: if the intersections of the hairs be at the same distance from the floats, the line joining these intersections will evidently be parallel to the lines joining the surfaces *a*, *b*, of the

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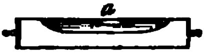
446. Explain the principle on which the water level with sights is constructed.

liquid, and will therefore be level. But if one of these points be more distant from the floats than the other, the line joining the intersections will point upward if viewed from the lower sight, and downward if viewed from the higher one.

The accuracy of the results of this instrument, will be greatly increased by lengthening the tube A.

447. *Spirit Level.*—The common *spirit level* consists of a glass tube, *Fig.* 101, filled with spirit of wine, excepting a small space in which there is left a bubble of air. This bubble, when the instrument is laid on a level surface, will be exactly in the middle of the tube, and therefore, to adjust a level, it is only necessary to bring the bubble to this position.

FIG. 101.



Spirit Level.

The glass tube is inclosed in a brass case, which is cut out on the upper side, so that the bubble may be seen, as represented in the figure.

448. This instrument is employed by builders to level their work, and is highly convenient for that purpose, since it is only necessary to lay it on a beam to try its level.

SPECIFIC GRAVITY.

449. *If a tumbler be filled with water to the brim, and an egg, or any other heavy solid, be dropped into it, a quantity of the fluid, exactly equal to the size of the egg, or other solid, will be displaced, and will flow over the side of the vessel.* Bodies which sink in water, therefore, displace a quantity of the fluid equal to their own bulks.

450. Now, it is found by experiment, that when any solid substance sinks in water, it loses, while in the fluid, a portion of its weight, just equal to that of the bulk of water which it displaces. This is readily made evident by experiment.

451. Take a piece of ivory, or any other substance that will sink in water, and weigh it accurately in the usual manner; then suspend it by a thread, or hair, in the empty cup A, *Fig.* 102, and balance it, as shown in the figure. Now pour water into the cup, and it will be found that the suspended body will lose a part of its weight, so that a certain number of grains

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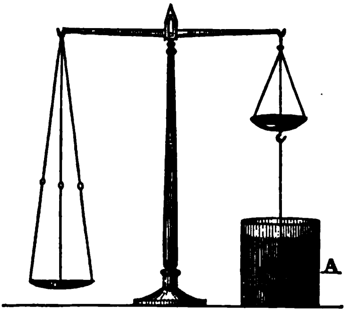
447. Describe the common spirit level, and the method of using it. 448. What is the use of the level? 449. How much water will an egg displace? 450. How much will a cubic inch of any substance weigh in water than in air? 451. How is it d by Fig. 102, that a body weighs less in water than in air?

must be taken from the opposite scale, in order to make the scales balance as before the water was poured in. The number of grains taken from the opposite scale, show the weight of a quantity of water equal to the bulk of the body so suspended.

FIG. 102.



Weighing in Water.

452. It is on the principle, that bodies weigh less in the water than they do when weighed out of it, or in the air, that water becomes the means of ascertaining their specific gravities, for it is by comparing the weight of a body *in* the water, with what it weighs *out* of it, that its specific gravity is determined.

Thus, suppose a cubic inch of gold weighs 19 ounces, and on being weighed in water, weighs only 18 ounces, or loses a nineteenth part of its weight, it will prove that gold, bulk for bulk, is nineteen times heavier than water, and thus 19 would be the specific gravity of gold. And so if a cube of copper weigh 9 ounces in the air, and only 8 ounces in the water, then copper, bulk for bulk, is 9 times as heavy as water, and therefore has a specific gravity of 9.

453. If the body weighs less, bulk for bulk, than water, it is obvious that it will not sink in it, and therefore weights must be added to the lighter body, to ascertain how much less it weighs than water.

The specific gravity of a body, then, is merely its weight compared with the same bulk of water; and water is thus made the standard by which the weights of all other bodies are compared.

454. *How to take the Specific Gravity.*—To take the specific gravity of a solid which sinks in water, first weigh the body in the usual manner, and note down the number of grains it weighs; then, with a hair, or fine thread, suspend it from the bottom of the scale-dish, in a vessel of water, as represented by *Fig.* 102. As it weighs less in water, weights must be added to the side of the scale where the body is suspended, until they

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452. On what principle are specific gravities found? 453. What is the specific gravity of a body? 454. How are the specific gravities of solid bodies taken?

exactly balance each other. Next, note down the number of grains so added, and they will show the difference between the weight of the body in air and in water.

455. It is obvious that the greater the specific gravity of the body, the less, comparatively, will be this difference, because each body displaces only its own bulk of water, and some bodies of the same bulk will weigh many times more than others.

456. For example, suppose that a piece of platina, weighing 22 ounces, will displace an ounce of water, while a piece of silver, weighing 22 ounces, will displace two ounces of water. The platina, therefore, when suspended as above described, will require one ounce to make the scales balance, while the same weight of silver will require two ounces for the same purpose. The platina, therefore, bulk for bulk, will weigh twice as much as the silver, and will have twice as much specific gravity.

Having noted down the difference between the weight of the body in air and in water, as above explained, the specific gravity is found by dividing the weight in air by the loss in water. The greater the loss, therefore, the less will be the specific gravity, the bulk being the same.

457. Thus, in the above example, 22 ounces of platina was supposed to lose one ounce in water, while 22 ounces of silver lost two ounces in water. Now, 22 divided by 1, the loss of the platina, is 22; and 22 divided by 2, the loss in the silver, is 11. So that the specific gravity of platina is 22, while that of silver is 11. The specific gravities of these metals are, however, a little less than here estimated.

458. TABLE OF SPECIFIC GRAVITIES.

Antimony,	7	Platinum,	20
Zinc,	7	" hammered,	22
Cast Iron,	7	Mercury,	14
Tin,	8	Agate,	2½
Cobalt,	8	Sulphur,	2
Steel,	8	Glass, crown,	2½
Copper,	9	" flint,	3½
Bismuth,	10	Rock, crystal,	2½
Silver,	10	Marble,	2½
Lead,	11	Diamonds,	3½
Gold,	19	Ruby, (oriental,)	4¼

This table being intended for common use, the fractions are omitted, and the nearest round numbers only given.

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455 Why does a heavy body weigh comparatively less in the water than a light one? 456. Having taken the difference between the weight of a body in air and in water, by what rule is its specific gravity found? 457. Give the example stated, and show how the difference between the specific gravities of platina and silver is found.

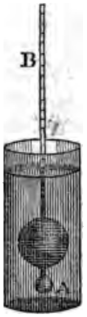
HYDROMETER.

459. *The hydrometer is an instrument by which the specific gravities of fluids are ascertained by the depth to which the instrument sinks below their surfaces.*

460. Suppose a cubic inch of lead loses, when weighed in water, 253 grains, and, when weighed in alcohol, only 209 grains, then, according to the principle already recited, a cubic inch of water actually weighs 253, and a cubic inch of alcohol 209 grains, for when a body is weighed in a fluid, it loses just the weight of the fluid it displaces.

461. Water, as we have already seen, (453,) is the standard by which the weights of other bodies are compared, and by ascertaining what a given bulk of any substance weighs in water, and then what it weighs in any other fluid, the comparative weight of water and this fluid will be known. For if, as in the above example, a certain bulk of water weighs 253 grains, and the same bulk of alcohol only 209 grains, then alcohol has a specific gravity nearly one-fourth less than water.

FIG. 103.



Hydrometer.

462. It is on this principle that the hydrometer is constructed. It is composed of a hollow ball of glass, or metal, with a graduated scale rising from its upper part, and a weight on its under part, which serves to balance it in the fluid.

Such an instrument is represented by *Fig.* 103, of which B is the graduated scale, and A, the weight, the hollow ball being between them.

463. To prepare this instrument for use, weights in grains, or half-grains, are put into the little cup, A, until the scale is carried down so that a certain mark on it coincides exactly with the surface of the water. This mark, then, becomes the standard of comparison between water and any other liquid in which the hydrometer is placed.

464. If plunged into a fluid lighter than water, it will sink below the mark, and, consequently, the fluid will rise higher on

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59. What is the hydrometer? 460. Suppose a cubic inch of any substance weighs grains less in water than in air, what is the actual weight of a cubic inch of wa- ? 461. On what principle is the hydrometer founded? 462. How is this instrument formed? 463. How is the hydrometer prepared for use? 464. How is it known by this instrument whether the fluid is lighter or heavier than water?

the scale. If the fluid is heavier than water, the scale will rise above the surface in proportion, and thus it is ascertained in a moment whether any fluid has a greater or less specific gravity than water.

To know precisely how much the fluid varies from the standard, the scale is marked off into degrees, which indicate grains by weight, so that it is ascertained very exactly how much the specific gravity of one fluid differs from that of another.

465. Water being the standard by which the weights of other substances are compared, it is placed as the unit, or point of comparison, and is, therefore, 1, 10, 100, or 1000, the ciphers being added whenever there are fractional parts expressing the specific gravity of the body. It is always understood, therefore, that the specific gravity of water is 1; and when it is said a body has a specific gravity of 2, it is only meant that such a body is, bulk for bulk, twice as heavy as water.

466. If the substance is lighter than water, it has a specific gravity of 0, with a fractional part. Thus, alcohol has a specific gravity of 0.809, that is, 809, water being 1000.

467. By means of this instrument, it can be told with great accuracy how much water has been added to spirits, for the greater the quantity of water, the higher will the scale rise above the surface.

The adulteration of milk with water, can also be readily detected with it, for as new milk has a specific gravity of 1032, water being 1000, a very small quantity of water mixed with it would be indicated by the instrument.

THE SIPHON.

468. Take a tube bent like the letter U, and, having filled it with water, place a finger on each end, and in this state plunge one of the ends into a vessel of water, so that the end in the water shall be a little the highest; then remove the fingers and the liquid will flow out, and continue to do so until the vessel is exhausted.

469. A tube acting in this manner is called a ***siphon***, and is

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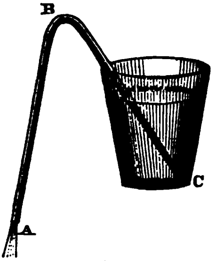
465. What is the standard by which the weights of other bodies are compared? What is the specific gravity of water? When it is said that the specific gravity of a body is 2, or 4, what meaning is intended to be conveyed? 466. If alcohol has a specific gravity of 809; what, in reference to this, is the specific gravity of water? 467. In what cases will the hydrometer detect fraud? 468. In what manner is a siphon made? 469. Explain the reason why the water ascends through one leg of the siphon. and descends through the other?

FIG. 104.

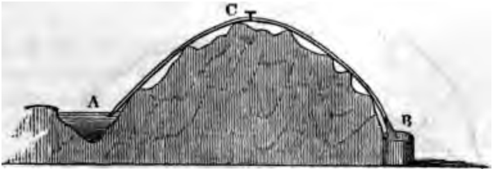


Siphon.

represented by *Fig.* 104. The reason why the water flows from the end of the tube, A, and, consequently, ascends through the other part, is, that there is a greater weight of the fluid from B to A, than from C to B, because the perpendicular height from B to A, is the greatest. The weight of the water from B to A, falling downward by its gravity, tends to form a vacuum, or void space, in that leg of the tube; but the pressure of the atmosphere on the water in the vessel, constantly forces the fluid up the other leg of the tube, to fill the void space, and thus the stream is continued as long as any water remains in the vessel.

470. *Application of the Siphon.*—The siphon is employed in draining mines, when there is a sufficient fall in the vicinity: it may also be used to convey water over a hill, provided the place where it is wanted is a foot or two lower than the fountain.

FIG. 105.



Application of the Siphon.

For this purpose, let A be a spring, *Fig.* 105, situated behind a hill, and it is desired to bring the water to B for family use. To do this, a lead tube, with a stop-cock at C, is carried over the hill, having also a stop-cock at each end. This done, and the two ends being closed, fill the two legs of the tube by pouring in water at C; then C being closed, let one person open the stop-cock at B, and a moment after, open that at A, and the water will instantly begin to flow from the spring to the reservoir, and if C is kept closed, will continue to run so long as the fountain furnishes water.

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470. Explain by Fig. 105, how the siphon conveys water over a hill.

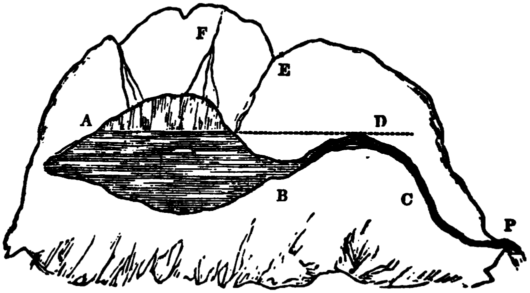
The principle of the siphon has been explained under *Fig.* 104.

INTERMITTING SPRINGS.

471. The action of the siphon depends upon the same principle as the action of the pump, namely, the pressure of the atmosphere, and, therefore, its explanation properly belongs to Pneumatics. It is introduced here merely for the purpose of illustrating the phenomena of intermitting springs, a subject which belongs to Hydrostatics.

Some springs, situated on the sides of mountains, flow, for a while, with great violence, and then cease entirely. After a time they begin to flow again, and then suddenly stop, as before. These are called *intermitting springs.* Among ignorant and superstitious people, these strange appearances have been attributed to witchcraft, or the influence of some supernatural power. But an acquaintance with the laws of nature will dissipate such ill-founded opinions, by showing that they owe their peculiarities to nothing more than natural siphons, existing in the mountains from whence the water flows.

FIG. 106.



Intermitting Spring.

472. *Fig.* 106 is the section of a mountain and spring, showing how the principle of the siphon operates to produce the effect described. Suppose there is a crevice, or hollow, in the rock from A to B, and a narrow fissure leading from it, in the form of the siphon, B C. The water from the rills F E,

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471. What is an intermitting spring? 472. How is the phenomenon of the intermitting spring explained?

filling the hollow, up to the line A D, it will then discharge itself through the siphon, and continue to run until the water is exhausted down to the leg of the siphon B, when it will cease. Then the water from the rills continuing to run until the hollow is again filled up to the same line, the siphon again begins to act, and again discharges the contents of the reservoir as before, and thus the spring P, at one moment flows with great violence and the next moment ceases entirely.

473. The hollow, above the line A D, is supposed not to be filled with the water at all, since the siphon begins to act whenever the fluid rises up to the bend D.

During the dry seasons of the year, it is obvious, that such a spring would cease to flow entirely, and would begin again only when the water from the mountain filled the cavity through the rills.

CHAPTER VI.

HYDRAULICS.

474. *It has been stated,* (410,) *that Hydrostatics is that branch of Natural Philosophy, which treats of the weight, pressure, and equilibrium of fluids, and that Hydraulics has for its object, the investigation of the laws which regulate fluids in motion.*

If the pupil has learned the principles on which the pressure and equilibrium of fluids depend, as explained under the former article, he will now be prepared to understand the laws which govern fluids when in motion.

475. The pressure of water downward, is in the same proportion to its height, as is the pressure of solids in the same direction.

476. Suppose a vessel of three inches in diameter has a billet of wood set up in it, so as to touch only the bottom, and suppose the piece of wood to be three feet long, and to weigh nine pounds; then the pressure on the bottom of the vessel will be

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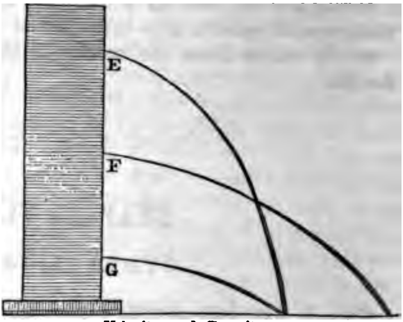
472. Explain Fig. 106, and show the reason why such a spring will flow and cease to flow, alternately. **474.** How does the science of Hydrostatics differ from that of Hydraulics? **475.** Does the downward pressure of water differ from the downward pressure of solids, in proportion? **476.** How is the downward pressure of water illustrated?

nine pounds. If another billet of wood be set on this, of the same dimensions, it will press on its top with the weight of nine pounds, and the pressure at the bottom will be eighteen pounds, and if a like billet be set on this, the pressure at the bottom will be twenty-seven pounds, and so on, in this ratio, to any height the column is carried.

Now the pressure of fluids is in the same proportion; and when confined in pipes, may be considered as one short column set on another, each of which increases the pressure of the lowest, in proportion to their number and height.

FIG. 107



Velocity and Gravity.

477. If a vessel, *Fig.* 107, be filled with water, and three apertures be made in its side at E F G, the fluid will be thrown out in jets, falling to the earth in the curved lines shown. The reason why these curves differ in shape, is, that the fluid is acted on by two forces, namely, the pressure of the water above the jet, which produces its velocity forward, and the action of gravity, which impels it downward. It therefore obeys the same laws that solids do when projected forward, and falls down in curved lines, the shapes of which depend on their relative velocities, (246.)

478. The quantity of water discharged, being in proportion to the pressure, when the orifices are the same, that discharged from each orifice will differ in quantity, according to the height of the water above it.

479. It is found, however, that the velocity with which a vessel discharges its contents, does not depend entirely on the pressure, but in part on the kind of orifice through which the liquid flows. It might be expected, for instance, that a tin ves-

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477. Why do the lines described by the jets from the vessel, Fig. 107, differ in shape? What two forces act upon the fluid as it is discharged, and how do these forces produce a curved line? 478. In what proportion do the orifices discharge the fluid? 479. Does the velocity with which a fluid is discharged, depend entirely on the pressure?

sel of a given capacity, with an orifice of, say an inch in diameter, would part with its contents sooner than another of the same capacity and orifice, whose side was an inch or two thick, since the friction through the tin might be considered much less than that presented by the other orifice.

480. But it has been found, by experiment, that the tin vessel does not part with its contents so soon as another vessel, of the same height and size of orifice, from which the water flowed through a short pipe. And, on varying the length of these pipes, it is found that the most rapid discharge, other circumstances being equal, is through a pipe, whose length is twice the diameter of its orifice. Such an aperture discharged 82 quarts, in the same time that another vessel of tin, without the pipe, discharged 62 quarts.

481. This surprising difference is accounted for, by supposing that the cross currents, made by the rushing of the water from different directions toward the orifice, mutually interfere with each other, by which the whole is broken, and thrown into confusion by the sharp edge of the tin, and hence the water issues in the form of spray, or of a screw, from such an orifice. A short pipe seems to correct this contention among opposing currents, and to smooth the passage of the whole, and hence we may observe, that from such a pipe, the stream is round and well defined.

482. *Proportion between the Pressure and the Velocity of Discharge.*—If a small orifice be made in the side of a vessel filled with any liquid, the liquid will flow out with a force and velocity equal to the pressure which the liquid before exerted on that portion of the side of the vessel before the orifice was made.

Now, as the pressure of fluids is as their heights, it follows, that if several such orifices are made, the lowest will discharge the greatest, while the highest will discharge the least quantity of the fluid.

The velocity of discharge, in the several orifices of such a vessel, will show a remarkable coincidence between the ratio of increase in the quantity of liquid, and the increased velocity of a falling body.

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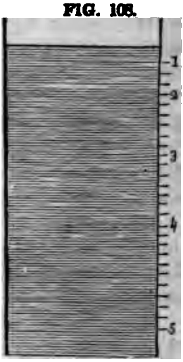
480. What circumstance, besides pressure, facilitates the discharge of water from an orifice? In a tube discharging water with the greatest velocity, what is the proportion between its diameter and its length? What is the proportion between the quantity of fluid discharged through an orifice of tin and through a short pipe? **481.** How is this difference explained? **482.** What are the proportions between the velocities of discharge and the heights of the orifices, as above explained?

FIG. 108.



Velocity of Discharge.

483. Thus, if the tall vessel, *Fig.* 108, of equal dimensions throughout, be filled with the water, and a small orifice be made at one inch from the top, or below the surface, as at 1; and another at 2, 4 inches below this; another at 9 inches; a fourth at 16 inches; and a fifth at 25 inches; then the velocities of discharge, from these several orifices, will be in proportion of 1, 2, 3, 4, 5.

484. To make this more obvious, we will place the expressions of the several velocities in the upper line of the following table, the lower numbers expressing the depths of the several orifices.

Velocity, ...	1	2	3	4	5	6	7	8	9	10
Depth, ...	1	4	9	16	25	36	49	64	81	100

Thus it appears, as in falling bodies, that to produce a twofold velocity a fourfold height is necessary. To obtain a threefold velocity of discharge, a ninefold height is required, and for a fourfold velocity, sixteen times the height, and so in this proportion, as shown by the table, (111.)

In order to establish the fact, that the velocity with which a liquid spouts from an orifice, is equal to the velocity which a body would acquire in falling unobstructed from the surface of the liquid to the depth of the orifice, it is only necessary to prove the truth of the principle in any one particular case.

Now it is manifestly true, if the orifice be presented downward, and the column of fluid over it be of small height, then this indefinitely small column will drop out of the orifice by the mere effect of its own weight, and, therefore, with the same velocity as any other falling body; but as fluids transmit pressure in all directions, the same effect will be produced, whatever may be the direction of the orifice.

FRICTION BETWEEN SOLIDS AND FLUIDS.

485. The rapidity with which water flows through pipes of the same diameter, is found to depend much on the nature

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483. If in Fig. 108, orifices are made at the distance of 1, 4, 9. 16, and 25 inches from the top, then in what ratio of velocity will the water be discharged? 484. How is it proved that the velocity of the spouting liquid is equal to that of a falling body? 485. Suppose a lead and a glass tube, of the same diameter; which will deliver the greatest quantity of liquid in the same time? Why will a glass tube deliver most?

of their internal surfaces. Thus a lead pipe, with a smooth aperture, under the same circumstances, will convey much more water than one of wood, where the surface is rough, or beset with points. In pipes, even where the surface is as smooth as glass, there is still considerable friction, for in all cases, the water is found to pass more rapidly in the middle of the stream than it does on the outside, where it rubs against the sides of the tube.

486. The sudden turns, or angles of a pipe, are also found to be a considerable obstacle to the rapid conveyance of the water, for such angles throw the fluid into eddies or currents by which its velocity is arrested.

In practice, therefore, sudden turns are generally avoided, and where it is necessary that the pipe should change its direction, it is done by means of as large a circle as convenient.

487. *Water in Pipes.*—Where it is proposed to convey a certain quantity of water to a considerable distance in pipes, there will be a great disappointment in respect to the quantity actually delivered, unless the engineer takes into account the friction, and the turnings of the pipes, and makes large allowances for these circumstances. If the quantity to be actually delivered ought to fill a two-inch pipe, one of three inches will not be too great an allowance, if the water is to be conveyed to any considerable distance.

In practice, it will be found that a pipe of two inches in diameter, one hundred feet long, will discharge about five times as much water as one of one inch in diameter of the same length, and under the same pressure.

488. This difference is accounted for, by supposing that both tubes retard the motion of the fluid, by friction, at equal distances from their inner surfaces, and consequently that the effect of this cause is much greater in proportion, in a small tube, than in a large one.

489. *Flowing of Rivers.*—The effect of friction in retarding the motion of fluids is perpetually illustrated in the flowing of rivers and brooks. On the side of a river, the water, especially where it is shallow, is nearly still, while in the middle of a stream it may run at the rate of five or six miles an hour. For the same reason, the water at the bottoms of rivers is much less

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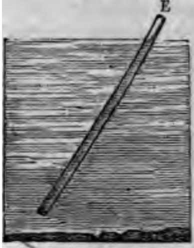
486. What is said of the sudden turnings of a tube, in retarding the motion of the fluid? 487. How much more water will a two-inch tube of a hundred feet long discharge, than a one-inch tube of the same length? 488. How is this difference accounted for? 489. How do rivers show the effect of friction in retarding the motion of their waters?

rapid than at the surface. This is often proved by the oblique position of floating substances, which in still water would assume a vertical direction.

FIG. 109.



River—Current.

Thus, suppose the stick of wood E, *Fig.* 109, to be loaded at one end with lead, of the same diameter as the wood, so as to make it stand upright in still water. In the current of a river, where the lower end nearly reaches the bottom, it will incline as in the figure, because the water is more rapid toward the surface than at the bottom, and hence the tendency of the upper end to move faster than the lower one, gives it an inclination forward.

MACHINES FOR RAISING WATER.

490. The common pump, though a hydraulic machine, depends on the pressure of the atmosphere for its effect, and therefore its explanation comes properly under the article Pneumatics, where the consequences of atmospheric pressure will be illustrated.

Such machines only as raise water without the assistance of the atmosphere, come properly under the present article.

491. ARCHIMEDES' SCREW.—Among these, one of the most curious, as well as ancient machines, is the *screw of Archimedes*, and which was invented by that celebrated philosopher, two hundred years before the Christian era, and then employed for raising water, and draining land in Egypt.

492. It consists of a tube, made of lead, or strong leather, coiled round a cylinder of wood or iron, as represented by *Fig.* 110. It has a support at each end, turning on gudgeons, the upper end being sometimes furnished with cog-wheels to give a more easy and rapid motion. Both ends are open, the lower one being placed so far under the water as not to allow the orifice to come above the surface in turning; the other discharges the water in an uninterrupted stream.

493. The angle at which these machines work depends on the manner of winding the tube on the cylinder; that is,

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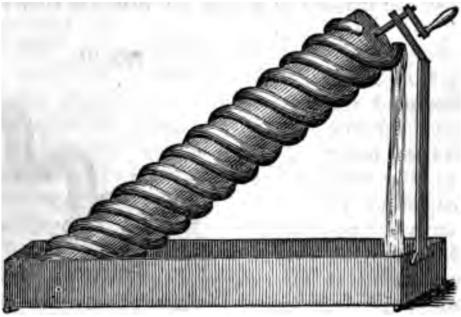
Explain Fig. 109. 490. What is said of the common pump? 491. Who is said to have been the inventor of Archimedes' screw? When was this screw invented? 492. Explain this machine, as represented in Fig. 110. and show how the water is elevated by turning it. 493. What must be the inclination of this machine?

FIG. 110.



Archimedes' Water Screw.

whether the folds touch each other, or are at a distance apart, for it is obvious that if the tube passes only a few times around the support, this must be in nearly a horizontal position to act; but if the folds nearly touch, as in the figure, it may be placed at an angle of about 50° with the horizon. It will be apparent that the direction of each fold must be toward the horizon, as the screw turns, otherwise the water would not run. This is shown by the figure. This machine, as above stated, is a very ancient invention, but has been re-invented in modern times, and employed in most parts of Europe.

It has been constructed in various ways besides that here represented. One was, to cut a spiral groove in a large log of wood, and cover this with metal, leather, or boards, so as to make it hold the water. The screw being thus sunk into the wood, instead of being on the outside, as commonly represented.

494. When it was necessary to raise the water to a great height, a series, one obliquely above the other, were employed, platforms being constructed, with vessels to contain the water, the lower end of the second screw taking that which was elevated by the first; the third receiving that carried up by the second, and so on. At present we believe this engine is no where used except as a curiosity, there being better means of raising water.

495. This principle is readily illustrated by winding a piece of lead tube round a walking-stick, and then turning the whole with one end in a dish of water, as shown in the figure.

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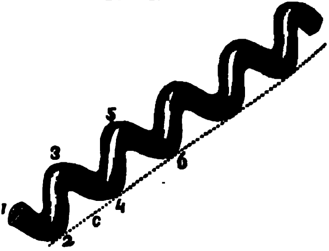
494. How was water raised to great heights by this machine? 495. How may the principle of Archimedes' screw be readily illustrated?

Theory of Archimedes' Screw.—By the following cut and explanation, the manner in which this machine acts will be understood.

FIG. 111.



496. Suppose the extremity 1, *Fig.* 111, to be presented upward, as in the figure, the screw itself being inclined as represented. Then, from its peculiar form and position, it is evident, that commencing at 1, the screw will descend until we arrive at a certain point, 2; in proceeding from 2 to 3, it will ascend. Thus, 2 is a point so situated that the parts of the screw on both sides of it ascend, and therefore if any body, as a ball, were placed in the tube at 2, it could not move in either direction without ascending. Again, the point 3 is so situated, that the tube on each side of it descends; and as we proceed we find another point, 4, which, like 2, is so placed, that the tube on both sides of it ascends, and, therefore, a body placed at 4, could not move without ascending. In like manner, there is a series of other points along the tube, from which it either descends or ascends, as is obvious by inspection.

Now let us suppose a ball, less in size than the bore of the tube, so as to move freely in it, to be dropped in at 1. As the tube descends from 1 to 2, the ball of course will descend down to 2, where it will remain at rest.

Next, suppose the ball to be fastened to the tube at 2, and suppose the screw to be turned nearly half round, so that the end 1 shall be turned downward, and the point 2 brought to the highest point of the curve 1, 2, 3.

497. The last movement of the spiral, it is evident, would so change the positions of the ascending and descending parts, as to continue the motion upward, but it must be remembered that the water differs from the ball used for illustration, in having a constant pressure downward, and consequently upward, and that the ascent of the water depends on this property of the action of fluids.

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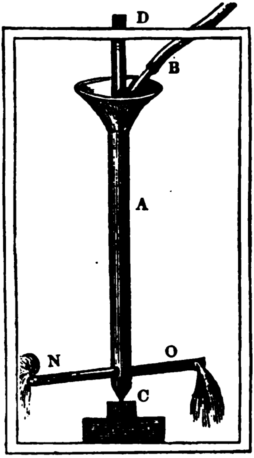
496. Explain the manner in which a ball would ascend, Fig. 111, by turning the screw. 497. On what property of fluids does the ascent of the water depend?

498. **Barker's Mill.**—For the different modes of applying water as a power for driving mills, and other useful purposes, we must refer the reader to works on practical mechanics. There is, however, one method of turning machinery by water, invented by Dr. Barker, which is strictly a philosophical, and, at the same time, a most curious invention, and therefore is properly introduced here.

This machine is called *Barker's centrifugal mill*, and such parts of it as are necessary to understand the principle on which it acts are represented by *Fig.* 112.

FIG. 112.



Centrifugal Mill.

The upright cylinder A, is a tube which has a funnel-shaped mouth for the admission of the stream of water from the pipe B. This tube is six or eight inches in diameter, and may be from ten to twenty feet long. The arms, N and O, are also tubes communicating freely with the upright one, from the opposite sides of which they proceed. The shaft D is firmly fastened to the inside of the tube, openings at the same time being left for the water to pass to the arms O and N. The lower part of the tube is solid, and turns on a point resting on a block of stone or iron, C. The arms are closed at their ends, near which are the orifices on the sides opposite to each other, so that the water spouting from them will fly in opposite directions. The stream from the pipe B, is regulated by a stop-cock, so as to keep the tube A constantly full without overflowing.

499. To set this engine in motion, nothing is required but the force of the water, which being let in by the pipe, descends, and spouting from the opposite orifices, the motion immediately begins, and if the main tube is of sufficient length, and kept full of water, it will in a few minutes acquire a whirling velocity which will astonish any one who has not before seen this curious machine.

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498. Describe Barker's centrifugal mill, Fig. 112. 499. How is this mill set in motion?

500. With respect to the theory of its motion, Euler, Gregory, Brande and others, have written; and it was formerly supposed to depend in part on the resistance of the atmosphere, but on trial it is said to revolve most rapidly in a vacuum. It is therefore difficult to explain very clearly on what its motion does depend. Dr. Gregory says, "In this machine the water does not act by its weight, or momentum, but by its centrifugal force, and the reaction that is produced by the flowing of the water on the point immediately behind the orifice of discharge." Dr. Brande says, "The resistance, or reaction generated by the water issuing from the holes, is such as to throw the vertical pipe with its arms and axis into rapid rotatory motion."

A model of the running part of this mill may be made by any tinner, for a few shillings, and may be kept in constant motion, as a curiosity, by the waste water from the water ram described a few pages hence. The shaft may be from two to four feet in length, and an inch or two in diameter, the arms being one-half or one-third this size. The orifices in the arms must be small, otherwise too much water will be required, the quantity discharged being much greater than might be supposed.

After a few revolutions, the machine will receive an additional impulse by the centrifugal force generated in the arms, and in consequence of this, a much more violent and rapid discharge of the water takes place, than would occur by the pressure of that in the upright tube alone. The centrifugal force, and the force of the discharge thus acting at the same time, and each increasing the force of the other, this machine revolves with great velocity and proportionate power. The friction which it has to overcome, when compared with that of other machines, is very slight, being chiefly at the point C, where the weight of the upright tube and its contents is sustained.

By fixing a cog-wheel to the shaft at D, motion may be given to any kind of machinery required.

Where the quantity of water is small, but its height considerable, this machine may be employed to great advantage, it being under such circumstances one of the most powerful engines ever invented.

CHAIN PUMP.

501. The principle of this machine is ancient, but instead of flat boards, as in *Fig.* 113, pots, or deep buckets, were em-

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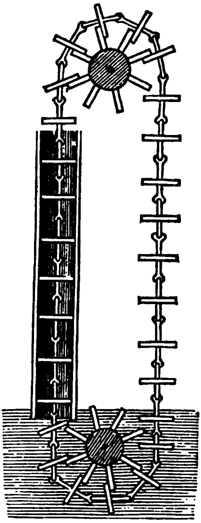
500. What is the theory of Barker's mill? 501. What is said of the antiquity and use of the chain-pump? Describe the construction and action of this machine.

ployed. Such engines are numerous along the banks of the Nile, and in Nubia and Hindostan, at the present day.

FIG. 113.



Chain Pump.

The construction, as well as the action of the chain-pump, will be understood by the figure. It consists of a number of square pieces of board, or of thin iron, connected together through their centers by iron rods, so that they can have no lateral motion. These rods are fastened to each other by hooks and eyes, thus forming a chain with long links. The ascending side of this chain passes through a square box, to which these pieces or buckets are closely fitted, but not so as to create much friction. The lower wheel, as well as the lower end of the box, must be placed below the surface of the water to be raised.

The action of this machine is described in few words. To the upper wheel is attached a crank; or if large quantities of water are to be raised, as on board of ships, mill work is added, to multiply the motion of the wheel, in order to give the buckets a more rapid ascent through the box. As the end of the box is constantly under the water, every board necessarily carries up a portion in its ascent, and although a single bucket would elevate but a small quantity up to the end of the box, yet as they follow each other in rapid succession, a constant stream is produced, and thus, when the trunk is a foot in diameter, and the power is sufficient, it will be obvious that a large quantity of water may, in a short time, be elevated by this means.

502. Although this machine is called a *pump*, it will be observed that the atmosphere is not concerned in its action.

WATER WHEELS.

503. Water wheels generally consist of a drum, or hollow cylinder, revolving on an axis, while the diameter or exterior surface is covered with *flat-boards*, *vanes*, or cavities called

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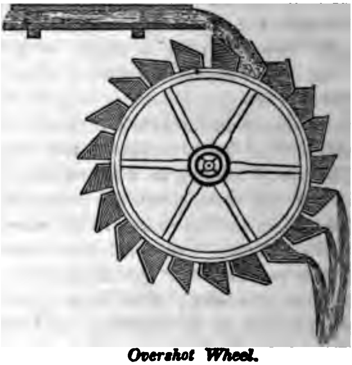
502. Does the chain-pump act by the pressure of the atmosphere or not? 503. Of what do all water wheels consist? How many kinds of water wheels are there, and what are their names?

buckets, upon which the water acts; first, to give motion to the wheel, and then to machinery. Such wheels are of three kinds, namely: the *overshot*, *undershot*, and *breast* wheels.

504. *Overshot Wheel.*—This wheel of all others, gives the greatest power with the least quantity of water, and is, therefore, generally used when circumstances will permit, or where there is a considerable fall, with a limited quantity of water.

505. The overshot wheel, *Fig.* 114, requires a fall equal at least to its own diameter, and it is customary to give it a greater length than other wheels, that the cells or buckets may contain a large quantity of water, for it is chiefly by the weight, and not the momentum of the fluid that this wheel is turned.

FIG. 114.



Overshot Wheel.

506. In its construction, the drum, or circumference is made water-tight, and to this are fixed narrow troughs or buckets, formed of iron, or boards, running the whole length of the drum. The water is conducted by a trough nearly level, and sometimes in width equal to the length of the wheel. It falls into the buckets on the top of the wheel, and hence the name *overshot.*

507. The buckets are so constructed as to retain the water until the wheel has made about one-third of a revolution from the place of admission, when it escapes as from an inverted vessel, and the wheel ascends with empty buckets, while on the opposite side they are filled with water, and thus the revolution is perpetuated. This whole machine and its action are so plain and obvious as to require no particular reference.

508. From the experiments of Mr. Smeaton, it appears, that the fall and quantity of water, and the diameter of the wheel being the same, the overshot, will produce about double the effect of the undershot wheel.

509. *Undershot Wheel.*—This is so called because the water

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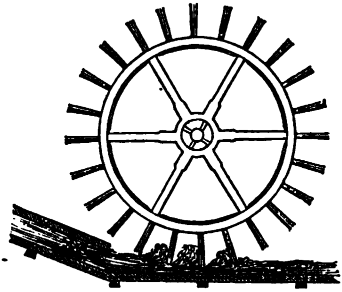
504. What is the chief advantage of the overshot wheel? 505. Is this wheel turned by the weight or momentum of the water? 506. Describe its construction. 507. What is said of the construction of the buckets? 508. Circumstances being equal, how much greater power has the overshot than the undershot wheel?

passes *under* instead of *over* the circumference, as in that above described. Hence it is moved by the momentum, not the weight of the water.

FIG. 115.



Undershot Wheel.

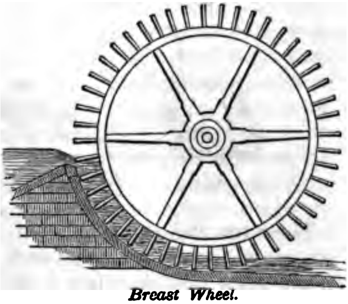
510. Its construction, as shown by *Fig.* 115, is different from the overshot, since instead of tight buckets to retain the water, it has *flat-boards*, standing like rays around the circumference.

511. Thus constructed, this wheel moves equally well whether the water acts on one or the other side of the boards, and hence is employed for tide-wheels, which turn in one direction when the tide is going out, and in the other when it is coming in.

This wheel requires a rapid flow, and a large quantity of water, to give it an efficient motion.

512. *Breast Wheel.*—This wheel, in its construction, or rather in the application of the moving power, is between the two wheels already described. In this the water, instead of passing over, or entirely under the wheel, is delivered in the direction of its center, *Fig.* 116. This is one of the most common wheels, and is employed where there is not a sufficient fall for the construction of the overshot kind.

FIG. 116.



Breast Wheel.

513. The breast wheel is moved partly by the weight, and partly by the momentum of the water. But notwithstanding this double force, this wheel is greatly inferior to the overshot,

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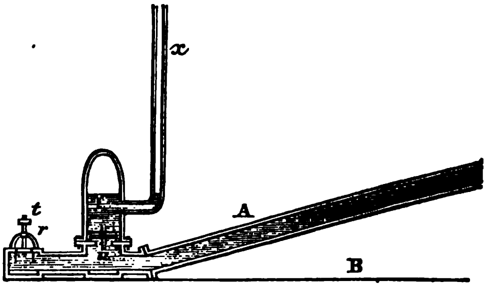
509. Where does the water pass in the undershot wheel? What kind of force moves this wheel? 510. How does its construction differ from the overshot wheel? 511. What is a tide-wheel? 512. How does the breast wheel differ from the overshot and undershot wheels? Where does the water strike this wheel? 513. By what power is the breast wheel moved? Why is this wheel inferior to the overshot?

in effect, not only because the lever power is diminished by the smaller diameter, but also on account of the great waste of water which always attends the best constructed wheels of this kind.

514. *General Remarks.*—In order to allow any of the above wheels to act with freedom, and to their fullest power, it is absolutely necessary that the water which is discharged, at the bottom of the wheel should have a wide and uninterrupted passage to run away, for whenever this is not the case it accumulates and forms a resistance to the action of the buckets or flat-boards, and thus subtracts just so much from the velocity and power of the machine.

515. HYDRAULIC, OR WATER RAM.—This beautiful engine was invented by Montgolfier, a Frenchman, (and the same who first ascended in a balloon,) in about 1796.

FIG. 117.



Hydraulic or Water Ram.

The form and construction of this useful machine, which is very simple in all its parts, will be understood by *Fig.* 117. Suppose the pipe A, comes from a spring, elevated a few feet above the horizontal line B, and that it conveys a constant stream of water. At the termination of this pipe, there is a valve, called a *spindle* valve, capable of closing its orifice when drawn upward; on the spindle *t*, are several small weights, by which the valve is made to drop down and remain open when the water is still; the weight of the whole being so nicely adjusted, that the movement of the running water will elevate it

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514. What cautions are necessary in order to permit any of the wheels described to produce their full effects? 515. Who invented the hydraulic, or water ram? Ex- n its construction by Fig. 117.

to its place, and thus stop the discharge. The weight of this valve, a nice point in the construction of the machine, must be just sufficient to make it rise by the force of the stream, and sink again when the water ceases to flow, thus rising and falling, and in effect causing the fluid to stop for an instant, and then renew its motion.

516. Now water in motion acquires a momentum in proportion to the length of the column, and the height of the source, and when in action exerts a force equal to that of a solid body of the same length and gravity, pressing downward from the same elevation. The inelasticity of the fluid gives it the property of acquiring motion through the whole length of a tube elevated at one extremity, whenever only a small portion is allowed to escape by its own pressure. Hence, when the valve opens by dropping down, all the water in the pipe, however long it may be, instantly moves forward to supply the place of that which has thus escaped; and if the pipe is long and the fountain high, ordinary metallic conductors are burst asunder by the shock whenever the stream is interrupted. It is on these principles of the force of water, that the Hydraulic Ram is founded; for when the stream is stopped by the rising of the valve, as already explained, an outlet is provided by another valve, *u*, opening upward into an air vessel, having a discharging pipe, *x*, and consequently when the spindle valve, *t*, is closed, this valve instantly opens, and the water is thrown with great force into the air vessel, and through the discharging pipe to the place where it is wanted. The stream being thus interrupted, and the water becoming still under the lower valve, this instantly opens by falling down, thus allowing the fluid to discharge itself at *r*, when the motion again raises the valve, and it is stopped, the valve *u* being raised for its escape as before; and thus this curious machine, if well constructed, will act with no other power or help, but a little stream of water, for weeks or months.

517. This engine affords the most efficient, cheap, and convenient means of raising water, for ornamental or farming purposes, ever invented. A spring on a hill near the house, or a running brook with an elevation of a few feet, is all the power required to supply an abundance of water for any private, or even public establishment. Mr. Millington, who erected many

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516. On what does the momentum of water in a tube depend? What is said of the motion of the water in the tube? 517. What is said of the economy and convenience of the water ram? To what heights will it throw water in proportion to the fall?

of these machines in England, states, that a very insignificant pressing column is capable of raising by the water ram, a very high ascending one, so that a sufficient fall may be obtained in almost any running brook, by erecting a dam at its upper end to produce a reservoir, and then carry the pipe down the natural channel until a sufficient fall is obtained. In this way a ram was made to raise one hundred hogsheads of water to the height of 134 feet, in 24 hours, with a fall of 4½ feet.

518. *Deaf and Dumb Asylum.*—The Deaf and Dumb Asylum, of Hartford, Ct., is supplied with water by means of Hydraulic rams, of which there are three, in case of accidents, though only two are kept in motion. The water is brought from the Little River, at the distance of half a mile, and is raised to the fourth story of the edifice, a height of 140 feet. The quantity delivered by two rams is about 35 hogsheads per day. The cost of the apparatus, including the stone structure for the rams and inclined tubes, was nearly $12,00.

CHAPTER VII.

PNEUMATICS.

519. *The term Pneumatics is derived from the Greek, pneuma, which signifies breath, or air. It is that science which investigates the mechanical properties of air, and other elastic fluids.*

Under the article *Hydrostatics*, (413,) it was stated that fluids were of two kinds, namely, *elastic*, and *non-elastic*, and that air and the gases belonged to the first kind, while water and other liquids belonged to the second.

520. The atmosphere which surrounds the earth, and in which we live, and a portion of which we take into our lungs at every breath, is called *air*, while the artificial products which possess the same mechanical properties, are called *gases*.

When, therefore, the word *air* is used in what follows, it will be understood to mean the atmosphere which we breathe.

521. *Air in all Porous Substances.*—Every hollow, crevice,

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519. What is meant by pneumatics? 520. What is air? What is gas? 521. What is meant when it is said that a vessel is filled with air? Is there any difficulty in expelling the air from vessels?

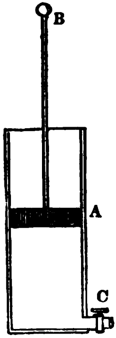
re, in solid bodies, not filled with a liquid, or some other nce, appears to be filled with air; thus a tube of any h, the bore of which is as small as it can be made, if kept will be filled with air; and hence, when it is said that a l is filled with air, it is only meant that the vessel is in its ary state. Indeed, this fluid finds its way into the most te pores of all substances, and can not be expelled and out of any vessel, without the assistance of the air-pump, me other mechanical means.

2. *Elasticity of Air.*—By the *elasticity* of air is meant its g, or the force with which it reacts, when compressed in a vessel. It is chiefly in respect to its elasticity and light- that the mechanical properties of air differ from those of r, and other liquids.

3. Elastic fluids differ from each other in respect to the *anency* of the elastic property. Thus, steam is elastic only s its heat is continued, and on cooling, returns again to the of water.

4. Some of the gases, also, on being strongly compressed, their elasticity, and take the form of liquids. But air differs these, in being permanently elastic; that is, if it be com- ed with ever so much force, and retained under compression ny length of time, it does not therefore lose lasticity, or disposition to regain its former , but always reacts with a force in propor- to the power by which it is compressed.

FIG. 118.



5. *Compression by Experiment*—Thus, if strong tube, or barrel, *Fig.* 118, be smooth, equal on the inside, and there be fitted to it olid piston or plug, A, so as to work up and n, air-tight, by the handle B, the air in the el may be compressed into a space a hundred s less than its usual bulk. Indeed, if the el be of sufficient strength, and the force em- ed sufficiently great, its bulk may be lessen- thousand times, or in any proportion, ac- ing to the force employed; and if kept in state for years, it will regain its former bulk instant the pressure is removed.

26. Thus, it is a general principle in Pneumatics, that air is pressible in proportion to the force employed.

. What is meant by the elasticity of air? 523. How does air differ from steam ome of the gases, in respect to its elasticity? 524. Does air lose its elastic by being compressed? 525. Explain by Fig. 118, how air may be compressed.

527. *Expansion of the Air.*—On the contrary, when the usual pressure of the atmosphere is removed from a portion of air, it expands and occupies a space larger than before; and it is found by experiment, that this expansion is in a ratio, as the removal of the pressure is more or less complete. Air also expands or increases in bulk, when heated.

528. If the stop-cock, C, *Fig.* 118, be opened, the piston, A, may be pushed down with ease, because the air contained in the barrel will be forced out at the aperture. Suppose the piston to be pushed down to within an inch of the bottom, and then the stop-cock closed, so that no air can enter below it. Now, on drawing the piston up to the top of the barrel, the inch of air will expand and fill the whole space, and were this space a thousand times as large, it would still be filled with the expanded air, because the piston removes the pressure of the external atmosphere from that within the barrel.

529. It follows, therefore, that the space which a given portion of air occupies, depends entirely on circumstances. If it is under pressure, its bulk will be diminished in exact proportion; and as the pressure is removed, it will expand in proportion, so as to occupy a thousand, or even a million times as much space as before.

530. *Weight of Air.*—Another property which air possesses is weight, or gravity. This property, it is obvious, must be slight, when compared with the weight of other bodies. But that air has a certain degree of gravity in common with other ponderous substances, is proved by direct experiment. Thus if the air be pumped out of a close vessel, and then the vessel be exactly weighed, it will be found to weigh more when the air is again admitted.

531. *Pressure of the Atmosphere.*—It is, however, the weight of the atmosphere which presses on every part of the earth's surface, and in which we live and move, as in an ocean, that here particularly claims our attention.

The pressure of the atmosphere may be easily shown by the tube and piston, *Fig.* 119.

Suppose there is an orifice to be opened or closed by the valve B, as the piston A is moved up or down in its barrel. The valve being fastened by a hinge on the upper side, on

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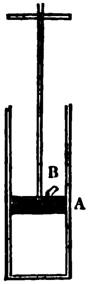
526. In what proportion to the force employed is the bulk of air lessened? 527. In what proportion will a quantity of air increase in bulk as the pressure is removed from it? 528. How is this illustrated by Fig. 118? 529. On what circumstances, therefore, will the bulk of a given portion of air depend? 530. How is it proved that air has weight? 531. Explain in what manner the pressure of the atmosphere is shown by Fig. 119.

FIG. 119.



pushing the piston down, it will open by the pressure of the air against it, and the air will make its escape. But when the piston is at the bottom of the barrel, on attempting to raise it again, toward the top, the valve is closed by the force of the external air acting upon it.

532. If, therefore, the piston be drawn up in this state, it must be against the pressure of the atmosphere, the whole weight of which, to an extent equal to the diameter of the piston, must be lifted, while there will remain a vacuum or void space below it in the tube.

533. If the piston be only three inches in diameter, it will require the full strength of a man to draw it to the top of the barrel, and when raised, if suddenly let go, it will be forced back again by the weight of the air, and will strike the bottom with great violence.

534. Supposing the surface of a man to be equal to 14½ square feet, and allowing the pressure on each square inch to be 15 lbs., such a man would sustain a pressure on his whole surface equal to nearly 14 tons.

Now, that it is the weight of the atmosphere which presses the piston down, is proved by the fact, that if its diameter be enlarged, a greater force, in exact proportion, will be required to raise it. And further, if when the piston is drawn to the top of the tube, a stop-cock, as at *Fig.* 118, be opened, and the air admitted under it, the piston will not be forced down in the least, because then the air will press as much on the under, as on the upper side of the piston.

535. By accurate experiments, an account of which it is not necessary here to detail, it is found that the weight of the atmosphere on every square inch of the surface of the earth is equal to fifteen pounds. If, then, a piston working air-tight in a barrel, be drawn up from its bottom, the force employed, besides the friction, will be just equal to that required to lift the same piston, under ordinary circumstances, with a weight laid on it equal to fifteen pounds for every square inch of surface.

536. The number of square inches in the surface of a piston

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532. The force pressing on the piston, when drawn upward, is sometimes called suction. 533. How is it proved that it is the weight of the atmosphere, instead of suction, which makes the piston rise with difficulty? 534. What is the pressure of the atmosphere on the surface of a man? 535. What is the pressure of the atmosphere on every square inch of surface on the earth? 536. What is the number of square inches in a circle of one foot in diameter? What is the weight of the atmosphere on the surface of a foot in diameter?

500. With respect to the theory of its motion, Euler, Gregory, Brande and others, have written; and it was formerly supposed to depend in part on the resistance of the atmosphere, but on trial it is said to revolve most rapidly in a vacuum. It is therefore difficult to explain very clearly on what its motion does depend. Dr. Gregory says, "In this machine the water does not act by its weight, or momentum, but by its centrifugal force, and the reaction that is produced by the flowing of the water on the point immediately behind the orifice of discharge." Dr. Brande says, "The resistance, or reaction generated by the water issuing from the holes, is such as to throw the vertical pipe with its arms and axis into rapid rotatory motion."

A model of the running part of this mill may be made by any tinner, for a few shillings, and may be kept in constant motion, as a curiosity, by the waste water from the water ram described a few pages hence. The shaft may be from two to four feet in length, and an inch or two in diameter, the arms being one-half or one-third this size. The orifices in the arms must be small, otherwise too much water will be required, the quantity discharged being much greater than might be supposed.

After a few revolutions, the machine will receive an additional impulse by the centrifugal force generated in the arms, and in consequence of this, a much more violent and rapid discharge of the water takes place, than would occur by the pressure of that in the upright tube alone. The centrifugal force, and the force of the discharge thus acting at the same time, and each increasing the force of the other, this machine revolves with great velocity and proportionate power. The friction which it has to overcome, when compared with that of other machines, is very slight, being chiefly at the point C, where the weight of the upright tube and its contents is sustained.

By fixing a cog-wheel to the shaft at D, motion may be given to any kind of machinery required.

Where the quantity of water is small, but its height considerable, this machine may be employed to great advantage, it being under such circumstances one of the most powerful engines ever invented.

CHAIN PUMP.

501. The principle of this machine is ancient, but instead of flat boards, as in *Fig.* 113, pots, or deep buckets, were em-

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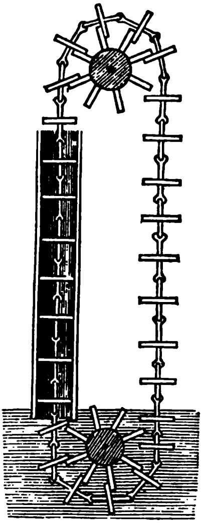
500. What is the theory of Barker's mill? 501. What is said of the antiquity and use of the chain-pump? Describe the construction and action of this machine.

ployed. Such engines are numerous along the banks of the Nile, and in Nubia and Hindostan, at the present day.

FIG. 113.



Chain Pump.

The construction, as well as the action of the chain-pump, will be understood by the figure. It consists of a number of square pieces of board, or of thin iron, connected together through their centers by iron rods, so that they can have no lateral motion. These rods are fastened to each other by hooks and eyes, thus forming a chain with long links. The ascending side of this chain passes through a square box, to which these pieces or buckets are closely fitted, but not so as to create much friction. The lower wheel, as well as the lower end of the box, must be placed below the surface of the water to be raised.

The action of this machine is described in few words. To the upper wheel is attached a crank; or if large quantities of water are to be raised, as on board of ships, mill work is added, to multiply the motion of the wheel, in order to give the buckets a more rapid ascent through the box. As the end of the box is constantly under the water, every board necessarily carries up a portion in its ascent, and although a single bucket would elevate but a small quantity up to the end of the box, yet as they follow each other in rapid succession, a constant stream is produced, and thus, when the trunk is a foot in diameter, and the power is sufficient, it will be obvious that a large quantity of water may, in a short time, be elevated by this means.

502. Although this machine is called a *pump*, it will be observed that the atmosphere is not concerned in its action.

WATER WHEELS.

503. Water wheels generally consist of a drum, or hollow cylinder, revolving on an axis, while the diameter or exterior surface is covered with *flat-boards*, *vanes*, or cavities called

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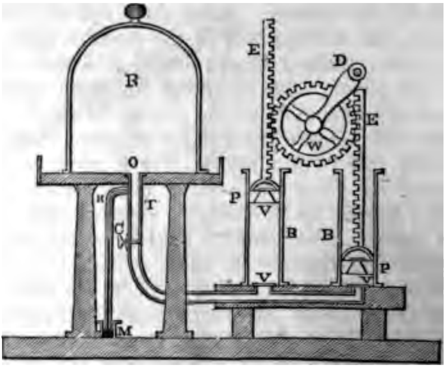
502. Does the chain-pump act by the pressure of the atmosphere or not? 503. Of what do all water wheels consist? How many kinds of water wheels are there, and what are their names?

FIG. 121.



Double-Acting Air Pump.

air, pressing on the mercury in the cup, elevates that in the tube, in proportion to the rarety of the air in the receiver.

Action.—The manner in which the double pump acts, is exactly similar to the single one, only that it has two barrels, or cylinders, instead of one. It is, therefore, unnecessary to repeat the explanation given under the last figure.

543. *External View of the Air Pump.*—Having explained the principles and action of the air pump, by figures showing its interior construction, we here present the student with an external view, *Fig.* 122, of the whole machine.

544. It is a small single-barrel pump, those with more barrels being of course more complex in structure, and less easily understood. The *barrel*, A, is seven inches high and two in diameter; the *plate*, K, is eight inches in diameter; the *piston rod*, B, works air-tight by means of the packing screw J, which is fitted to the *barrel case*, I. The piston is kept perpendicular by the *guide* E, through which it works; the *fulcrum prop*, H, is eighteen inches high, and the *parallel rods*, D, connect the piston rod and cross-head, C, with the lever.

The dome cap, I, contains a valve opening upward, for the escape of the air when the piston rises, This is the only valve in this pump, except that in the piston, which, as already shown, opens to admit the expanded air from the receiver, and force it

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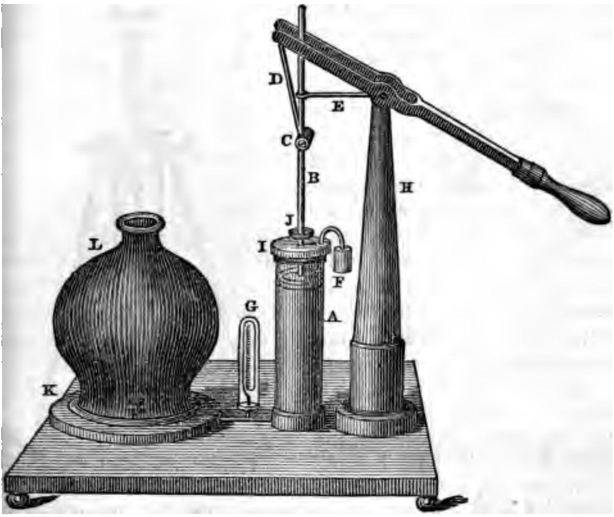
544. Explain all parts of the air pump by Fig. 122.

FIG. 122.



Single-Barrel Air Pump.

out at the upper valve. To the dome cap, above the valve, is fitted a *curved tube*, leading to the cistern, F; its use is to receive the waste oil which may escape from that used to lubricate the piston. The globular *bell-glass*, or receiver, L, is fitted by grinding to the brass plate on which it stands; the *barometer gauge*, G, contains mercury, and communicates with the tube leading from the barrel to the receiver; this shows by its scale what proportion of air is exhausted from the receiver; within the receiver there is seen a protuberance, showing the end of the exhausting tube, and into which may be screwed receivers or tubes for various experiments.

545. UPWARD ATMOSPHERIC PRESSURE.—The atmosphere, as we have seen, presses in every direction. Its upward pressure is shown by the apparatus, *Fig.* 123.

It consists of a hand air pump, *a*, with a valve opening upward, not shown. This pump is attached to a cylinder of larger size, *b*, in which is the piston, *c*, to which a 56-lb. weight is attached by a cord. This piston must be air-tight, and at the

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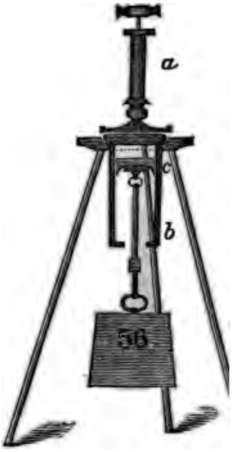
545. Describe Fig. 123, and show how the weight is elevated and sustained.

FIG. 1[illegible].



Upward Atmospheric Pres

lower part of the cylinder when the experiment begins. Now, on working the pump, a vacuum is formed between the pistons in the cylinder *b*, and consequently the pressure of the air on the under part of *c*, the cylinder being open, forces it upward, drawing the weight with it. On admitting the air into the large cylinder, from above, the weight instantly descends, showing that it is the pressure of the atmosphere from below which sustained the weight.

546. I. If a withered apple be placed under the receiver, and the air is exhausted, the apple will swell and become plump, in consequence of the expansion of the air which it contains within the skin.

II. Ether, placed in the same situation, soon begins without the influence of heat, because its particles, not the pressure of the atmosphere to force them together, with so much rapidity as to produce ebullition.

III. If a bladder partly filled with air, and the neck cured, has the external air exhausted, that within will so as to burst the membrane.

IV. If a flask partly filled with water, be placed, neck in a jar of the same fluid, under the receiver, the air within the flask will drive the water out, but it will again when the air is again let into the receiver.

V. If a burning taper be placed under it, the flan ceases for want of oxygen to support it. For the same no light is seen from the collision of flint and steel in a v

VI. If a bell be struck under the receiver, the sou grow faint as the air is exhausted, until it is no longer a See *Acoustics.*

547. *Magdeburgh Hemispheres.*—One of the most s

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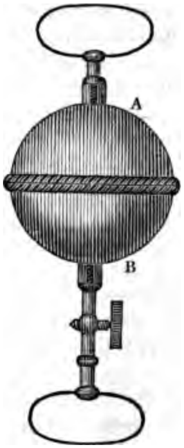
546. Why does an apple placed in the exhausted receiver grow plump? ether boil in the same situation? Why does flame cease in a vacuum? bell inaudible in a vacuum? 547. Describe the Magdeburgh hemispheres.

FIG. 124.

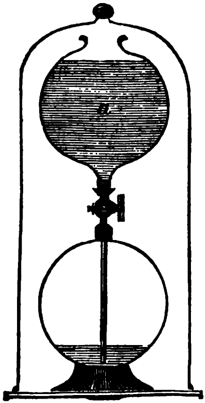


Magdeburgh Hemispheres.

illustrations of atmospheric pressure is made by means of the before named instrument, *Fig.* 124. It consists of two hemispheres of brass, A and B, fitted to each other by grinding, so that when put together they perfectly exclude the air. When put together without preparation, or in the usual manner, they hold no stronger than the parts of a snuff-box; but when the air is exhausted from within, it will take two strong men, if the diameter of the hemispheres are six inches, to pull them apart. The air is exhausted by unscrewing the lower handle and connecting that part with the exhausting tube of the air pump, and then by turning the key its return is prevented.

548. The amount of force required to separate them, will of course depend on their diameter and may be calculated by estimating the pressure to be equal to fifteen pounds for every square inch of surface, this, as we have seen, (536,) being the pressure of the atmosphere.

FIG. 125.



Expansion Fountain.

549. The same principle is involved when a piece of wet leather, with a string in the center, is pressed on a smooth stone, and then pulled by the string.

550. Expansion Fountain.—A very pretty experiment is made, with the air pump, by means of the apparatus, *Fig.* 125.

It consists of two glass globes, the upper one, *a*, being open at the top, and furnished with a stop-cock and jet tube, reaching nearly to the bottom of the lower globe.

The lower one, being nearly filled with some colored liquid, the upper one, with the jet, is screwed to it, as seen in the figure.

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548. What is the force required to pull them apart? 549. Why does a piece of wet leather adhere to a smooth surface? 550. Explain in what manner the fluid in the globes is made to rise, or fall, at pleasure.

Thus prepared, they are placed under the receiver of the air pump, and as the air is exhausted, that contained in the lower globe expands, and forces the liquid through the tube into the upper globe. On admitting the air into the receiver, the fluid again returns into the lower one, and this may be repeated any number of times, affording a very interesting experiment.

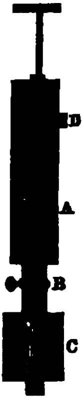
THE CONDENSER.

551. *The operation of the condenser is the reverse of that of the air pump, and is a much more simple machine.* The air pump, as we have just seen, will deprive a vessel of its ordinary quantity of air. The condenser, on the contrary, will double or treble the ordinary quantity of air in a close vessel, according to the force employed.

This instrument, *Fig.* 126, consists of a pump-barrel and piston, A, a stop-cock B, and the vessel C, furnished with a valve opening downward. The orifice, D, is to admit the air, when the piston is drawn up to the top of the barrel.

552. To describe its action, let the piston be above D, the orifice being open, and therefore the instrument filled with air, of the same density as the external atmosphere. Then, on forcing the piston down, the air in the pump-barrel, below the orifice D, will be compressed, and will rush through the stop-cock, B, into the vessel C, where it will be retained, because, on again moving the piston upward, the elasticity of the air will close the valve through which it was forced. On drawing the piston up again, another portion of air will rush in at the orifice D, and on forcing it down, this will also be driven into the vessel C; and this process may be continued as long as sufficient force is applied to move the piston, or there is sufficient strength in the vessel to retain the air. When the condensation is finished, the stop-cock B may be turned, to render the confinement of the air more secure.

FIG. 126.



Condenser.

553. Air Gun.—The magazines of air guns formerly consisted of a copper ball, which after being charged with condensed air, was screwed to the barrel, presenting an unseemly and in-

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551. How does the condenser differ from the air pump? 552. Explain Fig. 126, and show in what manner the air is condensed. 553. Explain the principle of the air gun.

convenient appendage. That here described, is a more recent and greatly improved invention.

In this, the breach of the gun is made of copper, and without much increasing the size, answers for the magazine, while the barrel serves as the tube of the condenser.

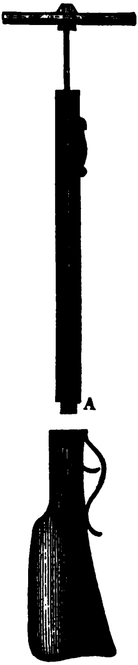
554. At A, *Fig.* 127, the barrel is screwed on to the breach, in which the air is condensed, by means of the piston, rod, and handle, as shown by the figure.

The piston is then withdrawn, the condensed air being prevented from escape by the valve, opening outward, as shown by the figure.

The ball being introduced, is fired by pulling back the trigger, which opens the valve, and allows a portion of the air to escape.

The velocity and force of the ball will depend on the amount of condensation in the magazine, and the smaller the tube and piston by which this is made, the greater of course will be the density of the confined air, and the more powerful the force by which the ball is impelled. Where the piston is no more than half or three quarters of an inch in diameter, it is said the ball will have a force not much short of that of a musket-shot.

FIG. 127.



Air Gun.

555. *Bottle Imp.*—A curious philosophical toy, called the *Bottle Imp*, shows in a very striking manner the effects of condensing a small portion of air.

Procure a glass jar, with a neck, as represented by *Fig.* 128, also a piece of India rubber, and a string to secure it over the mouth of the jar, so that it shall be perfectly air-tight. Next, take a piece of glass tube, about three-eighths of an inch in diameter, and with a file cut off pieces an inch long, and into one end of each put a cork stopper of such size as to make most of the cork swim on the surface when the tube is placed in the water. The tubes must now be partly filled with water, so that they will just balance themselves in the fluid without sinking, the air remaining in their upper halves.

Having prepared the tubes with their corks in this manner,

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554. With what force will the air gun throw a ball? 555. Explain the manner of constructing the bottle imp.

and placed them in the jar nearly filled with water, tie on the rubber cap with a good long string, so that no air can escape, and this little apparatus is finished.

FIG. 128.

Bottle Imp.

Now press upon the rubber with the hand, and the floating tubes will immediately begin to descend, and will strike the bottom of the jar, one after the other, with an audible stroke, and will rise again when the pressure ceases.

Many a philosophical head, on seeing this experiment for the first time, has been puzzled to assign any cause why these little objects should fall and rise in this manner, the hand not going near them, there being several inches of air between the cap and the water.

556. The explanation will be obvious on setting the jar between the light and the eye, and watching a tube when the pressure is made, for the water will be seen to rise in it at the moment it begins to fall, and sink again as it rises. The pressure of the hand is transmitted through the elastic rubber and air, to the water, and so to the air in the tube, which being thus condensed, takes in more water than its buoyancy can sustain, and it sinks—rising again when the air is allowed to expand, and drive out the water.

BAROMETER.

557. *The Barometer is an instrument which, by means of a column of mercury in a glass tube, shows, by its elevation and depression, the different degrees of atmospheric pressure.*

558. Suppose A, *Fig.* 129, to be a long tube, with the piston B so nicely fitted to its inside, as to work air-tight. If the lower end of the tube be dipped into water, and the piston drawn up by pulling at the handle C, the water will follow the piston so closely, as to be in contact with its surface, and apparently to be drawn up by the piston, as though the whole was one solid body. If the tube be thirty-five feet long, the water will continue to follow the piston, until it comes to the height of about thirty-three feet, where it will stop.

559. If the piston be drawn up still further, the water will

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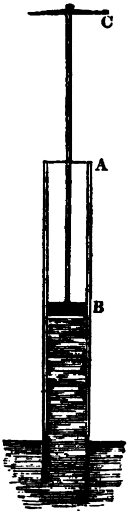
556. Explain the reason why the floats in the water imp are influenced by the pressure 557. What is the barometer? 558. Suppose the tube, Fig. 129, to stand with its lower end in the water, and the piston A to be drawn upward thirty-five feet, how far will the water follow the piston? 559. What will remain in the tube between the piston and the water, after the piston rises higher than thirty-three feet?

not follow it, but will remain stationary, the space from this height, between the piston and the water, being left a void space or vacuum.

FIG. 129.



560. The rising of the water in the above case, which only involves the principle of the common pump, is thought by some to be caused by *suction*, the piston *sucking* up the water as it is drawn upward. But according to the common notion attached to this term, there is no reason why the water should not continue to rise above the thirty-three feet, or why the power of suction should cease at that point, rather than at any other.

561. Without entering into any discussion on the absurd notions concerning this power, it is sufficient here to state, that it has long since been proved, that the elevation of the water, in the case above described, depends entirely on the weight and pressure of the atmosphere on that portion of the fluid which is on the outside of the tube. Hence, when the piston is drawn up under circumstances where the air can not act on the water around the tube, or pump-barrel, no elevation of the fluid will follow.

562. If an atmospheric pump, or even the suction-hose of a fire engine, be inserted into the side of a tight cask filled with fluid, all the force of what is called suction may be exerted by the pump or engine in vain; for the liquid will not rise until an aperture, admitting the atmosphere, is made in some part of the cask. It may be objected that wells, though covered several feet deep with earth, still admit water to be drawn from them by pumps, with all the facility of those which are open. But it must be remembered that the ground is porous, admitting the atmosphere to an unknown depth from the surface, and hence wells can not be covered by any common means so as to exclude sufficient atmospheric pressure for the purpose in question. That the pump will not raise water without the influence of the atmosphere, will be seen by the following experiment.

563. *Proof that the Pump acts by External Pressure.*—Suppose *Fig.* 130 to be the sections or halves, of two tubes, one

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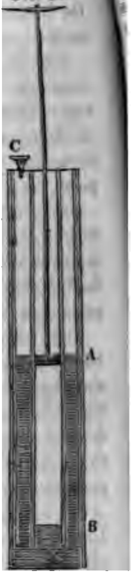
560. What is commonly supposed to make the water rise in such cases? Is there any reason why the suction should cease at thirty-three feet? 561. What is the true cause of the elevation of the water, when the piston, Fig. 129, is drawn up? 562. Will the suction-hose of a fire-engine raise water from a tight cask?

FIG. 130.



within the other, the outer one being made entirely close, so as to admit no air, and the space between the two being also made air-tight at the top. Suppose, also, that the inner tube being left open at the lower end, does not reach the bottom of the outer tube, and thus that an open space be left between the two tubes every where, except at their upper ends, where they are fastened together; and suppose that there is a valve in the piston, opening upward, so as to let the air which it contains escape, but which will close on drawing the piston upward. Now, let the piston be at A, and in this state pour water through the stop-cock, C, until the inner tube is filled up to the piston, and the space between the two tubes filled up to the same point, and then let the stop-cock be closed. If now the piston be drawn up to the top of the tube, the water will not follow it, as in the case of *Fig.* 129; it will only rise a few inches, in consequence of the elasticity of the air above the water, between the tubes, and in the space above the water, there will be formed a vacuum between the water and the piston, in the inner tube.

The reason why the result of this experiment differs from that before described, is, that the outer tube prevents the pressure of the atmosphere from forcing the water up the tube as the piston rises. This may be instantly proved, by opening the stop-cock C, and permitting the air to press upon the water, when it will be found, that as the air rushes in, the water will rise and fill the vacuum, up to the piston.

564. For the same reason, if a common pump be placed in a cistern of water, and the water is frozen over on its surface, so that no air can press upon the fluid, the piston of the pump might be worked in vain, for the water would not, as usual, obey its motion.

565. It follows, as a certain conclusion from such experiments, that when the lower end of a tube is placed in water, and the air from within removed by drawing up the piston, that it is the pressure of the atmosphere on the water around

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563. How is it shown by Fig. 130, that it is the pressure of the atmosphere which causes the water to rise in the pump-barrel? 564. Suppose the ice prevents the atmosphere from pressing on the water in a vessel, can the water be pumped out? 565. What conclusion follows from the experiments above described?

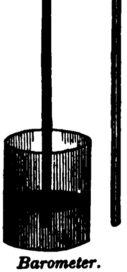
the tube, which forces the fluid up to fill the space thus left by the air.

566. It is also proved, that the weight, or pressure of the atmosphere, is equal to the weight of a perpendicular column of water 33 feet high, for it is found (*Fig.* 129) that the pressure of the atmosphere will not raise the water more than 33 feet, though a perfect vacuum be formed to any height above this point.

567. Experiments on other fluids, prove that this is the weight of the atmosphere, for if the end of the tube be dipped in any fluid, and the air be removed from the tube, above the fluid, it will rise to a greater or less height than water, in proportion as its specific gravity is less, or greater than that fluid.

568. *Mercury, or quicksilver*, has a specific gravity of about 13½ times greater than that of water, and mercury is found to rise about 29 inches in a tube under the same circumstances that water rises 33 feet. Now, 33 feet is 396 inches, which being divided by 29, gives nearly 13½, so that mercury being 13½ times heavier than water, the water will rise under the same pressure 13½ times higher than the mercury.

FIG. 131.



Barometer.

569. *Construction of the Barometer.*—The *barometer* is constructed on the principle of atmospheric pressure. This term is compounded of two Greek words, *baros*, weight, and *metron*, measure, the instrument being designed to measure the weight of the atmosphere.

Its construction is simple and easily understood, being merely a tube of glass, nearly filled with mercury, with its lower end placed in a dish of the same fluid, and the upper end furnished with a scale, to measure the height of the mercury.

570. Let A, *Fig.* 131, be such a tube, thirty-four or thirty-five inches long, closed at one end, and open at the other. To fill the tube, set it upright, and pour the mercury in at the open end, and when it is entirely full, place the fore-finger forcibly on

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566. How is it proved that the pressure of the atmosphere is equal to the weight of a column of water 33 feet high? 567. How do experiments on other fluids show that the pressure of the atmosphere is equal to the weight of a column of water 33 feet high? 568. How high does mercury rise in an exhausted tube? How does the height of mercury in the barometer indicate that of water?

this end, and then plunge the tube and finger under the surface of the mercury, before prepared in the cup, B. Then withdraw the finger, taking care that in doing this, the end of the tube is not raised above the mercury in the cup. When the finger is removed, the mercury will descend four or five inches, and after several vibrations, up and down, will rest at an elevation of 29 or 30 inches above the surface of that in the cup, as at C. Having fixed a scale to the upper part of the tube, to indicate the rise and fall of the mercury, the barometer would be finished, if intended to remain stationary. It is usual, however, to have the tube inclosed in a mahogany or brass case, to prevent its breaking, and to have the cup closed at the top, and fastened to the tube, so that it can be transported without danger of spilling the mercury.

571. *Cup of the Portable Barometer.*—The cup of the portable barometer also differs from that described, for were the mercury inclosed on all sides, in a cup of wood, or brass, the air would be prevented from acting upon it, and therefore the instrument would be useless. To remedy this defect, and still have the mercury perfectly inclosed, the bottom of the cup is made of leather, which, being elastic, the pressure of the atmosphere acts upon the mercury in the same manner as though it was not inclosed at all.

572. Below the leather bottom, there is a round plate of metal, an inch in diameter, which is fixed on the top of a screw, so that when the instrument is to be transported, by elevating this piece of metal, the mercury is thrown up to the top of the tube, and thus kept from playing backward and forward, when the barometer is in motion.

573. A person not acquainted with the principles of this instrument, on seeing the tube turned bottom upward, will be perplexed to understand why the mercury does not follow the common law of gravity, and descend into the cup; were the tube of glass 33 feet high, and filled with water, the lower end being dipped into a tumbler of the same fluid, the wonder would be still greater. But as philosophical facts, one is no more wonderful than the other, and both are readily explained by the principles above illustrated.

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569. What is the principle on which the barometer is constructed? 570. Describe the construction of the barometer, as represented by Fig. 131. 571. How is the cup of the portable barometer made so as to retain the mercury, and still allow the air to press upon it? 572. What is the use of the metallic plate and screw, under the bottom of the cup? 573. Explain the reason why the mercury does not fall out of the barometer tube when its open end is downward.

574. Water Barometer.—It has already been shown, (563,) that it is the pressure of the atmosphere on the fluid around the tube, by which the fluid within it is forced upward, when the pump is exhausted of its air. The pressure of the air, we have also seen, is equal to a column of water 33 feet high, or of a column of mercury 29 inches high. Suppose, then, a tube 33 feet high is filled with water, the air would then be entirely excluded, and were one of its ends closed, and the other end dipped in water, the effect would be the same as though both ends were closed, for the water would not escape, unless the air was permitted to rush in and fill up its place. The upper end being closed, the air could gain no access in that direction, and the open end being under water, is equally secure. The quantity of water in which the end of the tube is placed, is not essential, since the pressure of a column of water, an inch in diameter, provided it be 33 feet high, is just equal to a column of air of an inch in diameter, of the whole height of the atmosphere. Hence the water on the outside of the tube serves merely to guard against the entrance of the external air.

575. The same happens to the barometer tube, when filled with mercury. The mercury, in the first place, fills the tube perfectly, and therefore entirely excludes the air, so that when it is inverted in the cup or cistern, all the space above 29 inches is left a vacuum. The same effect precisely would be produced, were the tube exhausted of its air, and the open end placed in the cup; the mercury would run up the tube 29 inches, and then stop, all above that point being left a vacuum.

576. The mercury, therefore, is prevented from falling out of the tube, by the pressure of the atmosphere on that which remains in the cistern; for if this be removed, the air will enter, while the mercury will instantly begin to descend. This is called the *cistern* barometer.

577. Wheel Barometer.—In the common barometer, the rise and fall of the mercury is indicated by a scale of inches, and tenths of inches, fixed behind the tube; but it has been found that very slight variations in the density of the atmosphere are not readily perceived by this method. It being, however, desirable that these minute changes should be rendered more obvious, a contrivance for increasing the scale, called the *wheel* barometer, was invented.

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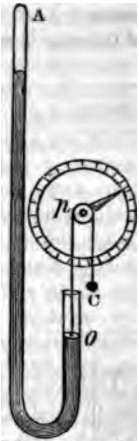
574. How high does the fluid stand in the water barometer? 575. What fills the space above 29 inches, in the barometer tube? 576. What prevents the mercury from falling out of the barometer tube? 577. In the common barometer, how is the rise and fall of the mercury indicated? Why was the wheel barometer invented?

FIG. 132.



Wheel Barometer.

578. The whole length of the tube of the wheel barometer, *Fig.* 132, from C to A, is 34 or 35 inches, and it is filled with mercury, as usual. The mercury rises in the short leg to the point *o*, where there is a small piece of glass floating on its surface, to which there is attached a silk string, passing over the pulley *p*. To the axis of the pulley is fixed an index, or hand, and behind this is a graduated circle, as seen in the figure. It is obvious, that a very slight variation in the height of the mercury at *o*, will be indicated by a considerable motion of the index, and thus changes in the weight of the atmosphere, hardly perceptible by the common barometer, will become quite apparent by this.

579. *Heights Measured by the Barometer.*—The mercury in the barometer tube being sustained by the pressure of the atmosphere, and its medium altitude at the surface of the earth being 29 to 30 inches, it might be expected that if the instrument was carried to a height from the earth's surface, the mercury would suffer a proportionate fall, because the pressure must be less at a distance from the earth, than at its surface, and experiment proves this to be the case. When, therefore, this instrument is elevated to any considerable height, the descent of the mercury becomes perceptible. Even when it is carried to the top of a hill, or high tower, there is a sensible depression of the fluid, so that the barometer is employed to measure the height of mountains and the elevation to which balloons ascend from the surface of the earth. On the top of Mont Blanc, which is about 16,000 feet above the level of the sea, the medium elevation of the mercury in the tube is only 14 inches, while on the surface of the earth, as above stated, it is 29 to 30 inches.

580. *Diminution of Density.*—The following table shows at what rate the atmosphere decreases in density, as indicated by the barometer. A part of these numbers are from actual ob-

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578. Explain Fig. 132, and describe the construction of the wheel barometer. 579. What is stated to be the medium range of the barometer at the surface of the earth? Suppose the instrument is elevated from the earth, what is the effect on the mercury? How does the barometer indicate the height of mountains? 580. Explain by the table the correspondence between the height, the fall of the mercury, and the temperature.

servations made from ascents in balloons, and a part from estimates. The medium pressure of the atmosphere, at the level of the sea, is estimated at 30 inches, and is expressed by 0.

HEIGHT IN MILES.	PRESSURE.	TEMPERATURE.
	Inches.	Fahr.
0	30.00	50.0
1	24.61	35.0
2	20.07	19.5
3	16.35	3.4
4	13.06	13.3
5	10.41	30.6
10	2.81	126.4
15	.45	240.6

Thus, according to this estimate, at the height of fifteen miles, the mercury falls to less than half an inch, while the cold is equal to 240 degrees below the zero of Fahrenheit.

581. *Principles of the Barometer applied to the Water Pump.*—As the efficacy of the pump depends on the pressure of the atmosphere, the barometer will always indicate the height to which it can be effectual at any given place. Thus, on Mont Blanc, where the barometer stands at only 14 inches, being less than one-half its height on the sea level, the water pump would only raise the fluid about 15 feet. Hence, engineers and others, who visit elevated countries, should calculate by the barometer, from what depth they can raise water by ærial pressure, before they erect works for this purpose.

At the city of Mexico and at Quito, for instance, the suction tube can only act to the depth of 22 or 20 feet, while on the Himalay mountains its rise will be only about 8 or 10 feet.

582. USE AS A WEATHER GLASS.—While the barometer stands in the same place, near the level of the sea, the mercury seldom or never falls below 28 inches, or rises above 31 inches; its whole range, while stationary, being only about 3 inches.

583. These changes in the weight of the atmosphere; indicate corresponding changes in the weather, for it is found, by watching these variations in the height of the mercury, that when it falls, cloudy or falling weather ensues, and that when

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581. How high will the pump raise water on Mont Blanc? To what height in Mexico and Quito? 582. How many inches does a fixed barometer vary in height? 583. When the mercury falls, what kind of weather is indicated? When the mercury rises, what kind of weather may be expected? When fog and smoke descend toward the ground, is it a sign of a light or heavy atmosphere?

it rises, fine clear weather may be expected. During the time when the weather is damp and lowering, and the smoke of chimneys descends toward the ground, the mercury remains depressed, indicating that the weight of the atmosphere, during such weather, is less than it is when the sky is clear. This contradicts the common opinion, that the air is the heaviest when it contains the greatest quantity of fog and smoke, and that it is the uncommon weight of the atmosphere which presses these vapors toward the ground.

584. A little consideration will show, that in this case the popular belief is erroneous, for not only the barometer, but all the experiments we have detailed on the subject of specific gravity, tend to show that the lighter any fluid is, the deeper any substance of a given weight will sink in it. Common observation ought, therefore, to correct this error, for every body knows that a heavy body will sink in water, while a light one will swim, and by the same kind of reasoning ought to consider, that the particles of vapor would descend through a light atmosphere, while they would be pressed up into the higher regions by a heavier air.

585. The following indications of the barometer with respect to the weather, may be depended on as correct, being tested by the observations of the author:—

I. In calm weather, when the wind, clouds, or sun, indicate approaching rain, the mercury in the barometer is low.

II. In serene, fine, settled weather, the mercury is high, and often remains so for days.

III. Before great winds, and during their continuance, from whatever quarter they come, the mercury sinks lowest, and especially if they come from the south.

IV. During the coldest, clear days, when a gentle wind from the north or west prevails, the mercury stands highest.

V. After great storms, when the mercury has been lowest, it rises most rapidly.

VI. It often requires considerable time for the mercury to gain its wonted elevation after a storm; and on the contrary, it sometimes rains without the usual corresponding change in its altitude.

VII. In general, whether there are any appearances of change in the horizon or not, we may prognosticate rain whenever the mercury sinks during fine weather.

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584. By what analogy is it shown that the air is lightest when filled with vapor?
585. Mention the indications of the barometer concerning the weather.

VIII. When it rains with the mercury high, we may be sure that it will soon be fair.

586. Use at Sea.—The principal use of the barometer, is on board of ships, where it is employed to indicate the approach of storms, and thus to give an opportunity of preparing accordingly; and it is found that the mercury suffers a most remarkable depression before the approach of violent winds, or hurricanes. The watchful captain, particularly in southern latitudes, is always attentive to this monitor, and when he observes the mercury to sink suddenly, takes his measures without delay to meet the tempest. During a violent storm, we have seen the wheel barometer sink a hundred degrees in a few hours.

587. *Preservation by the Barometer.*—But we can not illustrate the use of this instrument at sea better than to give the following extract from Dr. Arnot, who was himself present at the time. "It was," he says, "in a southern latitude. The sun had just set with a placid appearance, closing a beautiful afternoon, and the usual mirth of the evening watch proceeded, when the captain's orders came to prepare with all haste for a storm. The barometer had begun to fall with appalling rapidity. As yet, the oldest sailors had not perceived even a threatening in the sky, and were surprised at the extent and hurry of the preparations; but the required measures were not completed, when a more awful hurricane burst upon them than the most experienced had ever braved. Nothing could withstand it; the sails, already furled, and closely bound to the yards, were riven into tatters; even the bare yards and masts were in a great measure disabled; and at one time the whole rigging had nearly fallen by the board. Such, for a few hours, was the mingled roar of the hurricane above, of the waves around, and the incessant peals of thunder, that no human voice could be heard, and amidst the general consternation, even the trumpet sounded in vain. On that awful night, but for a little tube of mercury which had given the warning, neither the strength of the noble ship, nor the skill and energies of her commander, could have saved one man to tell the tale."

WATER PUMPS.

588. *The efficacy of the common pump in raising water, depends upon the force of atmospheric pressure, the principles of*

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586. Of what use is the barometer on board of ships? When does the mercury suffer the most remarkable depression? 587. What remarkable instance is stated, where a ship seemed to be saved by the use of the barometer? 588. On what does the efficacy of the common pump depend?

which have been fully illustrated under the articles, Air Pump and Barometer.

589. An experiment, of which few are ignorant, and which all can make, shows the principle of the pump in a very striking manner. If one end of a straw be dipped into a vessel of liquid, and the other end be sucked, the liquid will rise into the mouth, and may be swallowed.

The principles which this experiment involves are exactly the same as those concerned in raising water by the pump. The vessel of liquid answers to the well, the straw to the pump log, and the mouth acts as the piston, by which the air is removed.

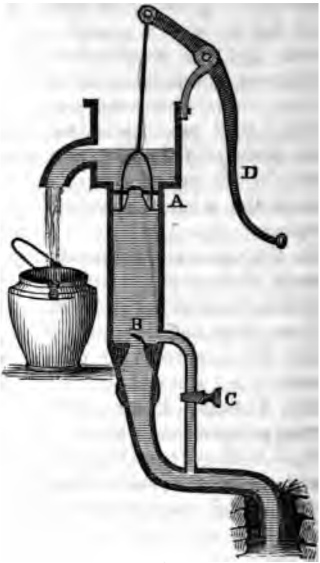
Water pumps are of three kinds, namely, the *sucking*, or *common* pump, the *lifting* pump, and the *forcing* pump.

590. COMMON METALLIC PUMP.—This (*Fig.* 133,) consists of a brass or iron barrel, A, containing at its upper part a hollow piston and valve, opening upward. Below this there is another valve, also opening upward. The pipe and stop-cock C, are for the purpose of letting the water from the barrel to the tube, which descends into the well.

The action of this pump depends on the pressure of the atmosphere, and will be readily understood by the pupil who has learned what is said under the articles *air pump* and *barometer*.

591. On raising the lever, D, the piston, A, descends down the barrel, the lower valve, B, at the same moment closing by the weight of the water, while the up-

FIG. 133.



Common Metallic Pump.

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589. What experiment is stated, as illustrating the principle of the common pump? How many kinds of pumps are mentioned? 590. Which kind is the common? Describe the common pump. Explain how the common pump acts. 591. When the lever is raised, what takes place in the pump-barrel? When it is depressed, what takes place?

ens and lets the water through. Then, on depress-
rer, the piston rises, its valve closing, and elevating
above it. By this action a vacuum would be formed
e two valves, did not the lower one open and admit
through the pipe above it. The lever again being
e same process is repeated, and the water is elevated
it in an interrupted stream.

a, with the stop-cock C, leading from the barrel to
added for the purpose of letting the water escape
mer in cold weather, and thus prevent its freezing.
though, in common language, this is called the suc-
, still it will be observed that the water is elevated
, or, in more philosophical terms, by atmospheric
nly above the valve A, after which it is raised by *lift-*
he spout. The water, therefore, is pressed into the
el by the atmosphere, and thrown out by the power
r.

TING PUMP.—The
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forcing it upward,
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suction pump, the
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RCING PUMP.—The
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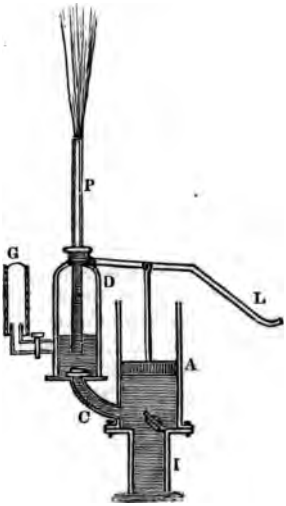
l by *Fig.* 134, where A is a solid piston, working

FIG. 134.



Forcing Pump.

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r is the water raised by atmospheric pressure, and how far by lifting?
the lifting pump differ from the common pump? 594. How does the
differ from the common pump?

air-tight in its barrel. The tube, C, leads from the barrel to the air-vessel, D. Through the pipe, P, the water is thrown into the open air. G is a guage, by which the pressure of the water in the air-vessel is ascertained. Through the pipe I, the water ascends into the barrel, its upper end being furnished with a valve opening upward.

To explain the action of this pump, suppose the piston to be down to the bottom of the barrel, and then to be raised upward by the lever L; the tendency to form a vacuum in the barrel, will bring the water up through the pipe I, by the pressure of the atmosphere. Then, on depressing the piston, the valve at the bottom of the barrel will be closed, and the water, not finding admittance through the pipe, whence it came, will be forced through the pipe C, and opening the valve at its upper end, will enter into the air-vessel D, and be discharged through the pipe P, into the open air.

The water is therefore elevated to the piston-barrel by the pressure of the atmosphere, and afterward thrown out by the force of the piston. It is obvious, that by this arrangement, the height to which this fluid may be thrown, will depend on the power applied to the lever, and the strength with which the pump is made.

596. The air-vessel D contains air in its upper part only, the lower part, as we have already seen, being filled with water. The pipe P, called the discharging pipe, passes down into the water, so that the air can not escape. The air is therefore compressed, as the water is forced into the lower part of the vessel, and reacting upon the fluid by its elasticity, throws it out of the pipe in a continued stream. The constant stream which is emitted from the direction pipe of the fire-engine, is entirely owing to the compression and elasticity of the air in its air-vessel. In pumps, without such a vessel, as the water is forced upward only while the piston is acting upon it, there must be an interruption of the stream while the piston is ascending, as in the common pump. The air-vessel is a remedy for this defect, and is found also to render the labor of drawing the water more easy, because the force with which the air in the vessel acts on the water, is always in addition to that given by the force of the piston.

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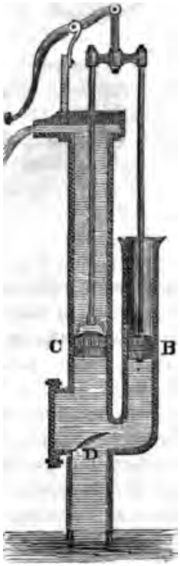
595. Explain Fig. 134, and show in what manner the water is brought up through the pipe I, and afterward thrown out at the pipe P. 596. Why does not the air escape from the air-vessel in this pump? What effect does the air-vessel have on the stream discharged? Why does the air-vessel render the labor of raising the water more easy?

597. Atmospheric and Forcing Pump.—A curious combination of the atmospheric and forcing pumps, is the following, *Fig.* 135.

FIG. 135.



Atmospheric and Forcing Pump.

The atmospheric, is furnished with a rod and piston, with the valve C, opening in the usual manner. The forcing piston B, is of solid metal, working water-tight in its barrel. The barrels are joined below the valve D, their pistons being also connected by a cross-bar, A, between the rods, so that they rise and fall together.

Now when the lever is depressed, and the pistons raised, the water above the valve C is discharged at the spout in the manner of the common suction pump, and the space is filled by atmospheric pressure through the lower valve D, by the suction pipe. When the pistons descend, this valve closes, and the solid piston B, drives the water through the valve C, and above that piston and to the spout. Thus one piston operates when the lever rises, and the other when it falls, producing in effect a constant stream of water from the spout.

In the construction of this pump, it should be considered that as both cylinders are filled at the same time, the suction pipe ought to be large in proportion.

598. Stomach Pump.—The design of this pump, of which there are several varieties, is to throw a fluid into the stomach, and again to withdraw it without changing the apparatus, but only its *position*. In cases of poisoning, the contents of the stomach may thus be diluted and withdrawn, including the deleterious matter, and thus the life of the individual be saved.

599. That here described is from the Journal of the Franklin Institute. It consists of a common metallic syringe, A, *Fig.* 136, screwed to a cylindrical valve-box, B, which contains two ovoid cavities, in each of which there is a loose, spherical metallic valve. The ends of the cavities are pierced, and the valves

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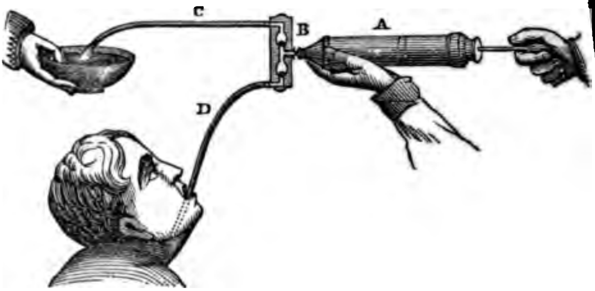
597. What is the difference between the pump, Fig. 135, and the common atmospheric and forcing pump? 598. What is the use of the stomach pump? 599. Describe the stomach pump, and show the reason why it acts in opposite ways on being turned over.

FIG. 136.



Stomach Pump.

fit exactly, either of the orifices. Thus it makes no difference which end of the valve-box is upturned, the valve falling down and closing the orifices in either direction. The flexible India rubber tubes, C D, are attached to the opposite ends of the cavities.

Now suppose the then upper tube is introduced into the stomach, and the lower one into a basin of warm water; in this position, on working the syringe the liquid would be injected into the stomach, and the poison diluted; then on reversing the position, by turning the syringe in the hand, without withdrawing the tube from the stomach, the valves drop on the other orifices, and the water is pumped from the stomach into the basin, as represented by the figure.

This is an interesting and beautiful invention, and no doubt has been the instrument of saving many human lives in cases of poisoning.

600. Fire Engine.—The *fire engine* is a modification of the forcing pump. It consists of two such pumps, the pistons of which are moved by a lever with equal arms, the common fulcrum being at C, *Fig.* 137. While the piston A is descending, the other piston, B, is ascending. The water is forced by the pressure of the atmosphere, through the common pipe P, and then dividing, ascends into the working barrels of each piston, where the valves, on both sides, prevent its return. By the alternate depression of the pistons, it is then forced into the air-box D, and then, by the direction pipe E, is thrown where it is

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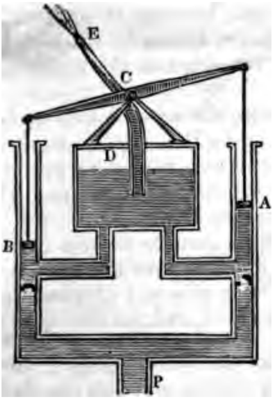
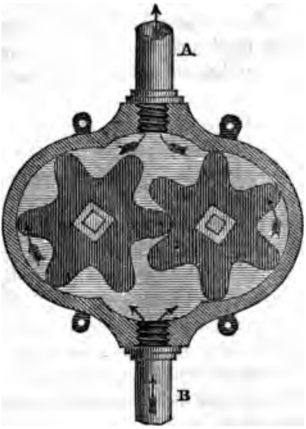
600. Explain Fig. 137, and describe the action of the fire engine. What causes the continued stream from the direction pipe of this engine?

FIG. 137.



Fire Engine.

FIG. 138.



Rotary Pump.

wanted. This machine acts precisely like the forcing pump, only that its power is doubled, by having two pistons instead of one.

601. Rotary Pump.—This is an ancient invention, though more than once re-invented and constructed in various forms in modern times. That here represented, *Fig.* 138, according to Mr. Ewbank, from whom the cut is taken, is one of the oldest, as well as best, ever constructed.

The design is to produce a continued stream, by simply turning a crank, thus converting the piston into cog-wheels, and the vertical motion into a rotary one.

Its construction is as follows: Two metallic cog-wheels, with obtuse teeth, are inclosed in a metallic case, so nicely fitted to each other that the water can not escape between them. The teeth also work so accurately between each other as to retain the fluid. The axle of one of the wheels is continued through one side of the case to receive the crank by which it is turned, the joint being secured by a collar of leather.

One side of the case being removed in the figure to show the construction, it will be observed that the motion of one wheel

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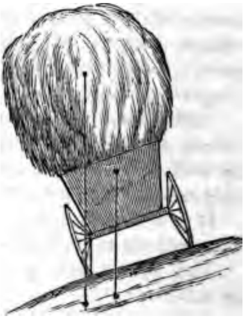
601. What is said of the antiquity of the rotary pump? Explain its construction by the figure. What objection to this pump is stated?

FIG. 34.



Load of Hay.

223. *Center of gravity in man.*—In man the center of gravity is between the hips, and hence, were his feet tied together, and his arms tied to his sides, a very slight inclination of his body would carry the perpendicular of his center of gravity beyond the base, and he would fall. But when his limbs are free to move, he widens his base, and changes this center at pleasure, by throwing out his arms, as circumstances require.

When a man runs, he inclines forward, so that the center of gravity may hang before his base, and in this position he is obliged to keep his feet constantly advancing, otherwise he would fall forward.

A man standing on one foot, can not throw his body forward without, at the same time, throwing his other foot backward, in order to keep the center of gravity within the base.

224. A man, therefore, standing with his heels against a perpendicular wall, can not stoop forward without falling, because the wall prevents his throwing any part of his body backward. A person, little versed in such things, agreed to pay a certain sum of money for an opportunity of possessing himself of double the sum, by taking it from the floor with his heels against the wall. The man, of course, lost his money, for in such a posture, one can hardly reach lower than his own knee.

225. The base on which a man is supported, in walking or standing, is his feet, and the space between them. By turning the toes out, this base is made broader, without taking much from its length, and hence persons who turn their toes outward, not only walk more firmly, but more gracefully, than those who turn them inward.

226. In consequence of the upright position of man, he is constantly obliged to employ some exertion to keep his balance. This seems to be the reason why children learn to walk with so much difficulty; for after they have strength to stand, it requires considerable experience so to balance the body as to set one foot before the other without falling.

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223. Where is the center of man's gravity? Why will a man fall with a slight inclination, when his feet and arms are tied? 224. Why can not one who stands with his heels against a wall stoop forward? 225. Why does a person walk most firmly, who turns his toes outward? 226. Why does not a child walk as soon as he can stand?

227. By experience in the art of balancing, or of keeping the center of gravity in a line over the base, men sometimes perform things that, at first sight, appear altogether beyond human power, such as dining with the table and chair standing on a single rope, dancing on a wire, &c.

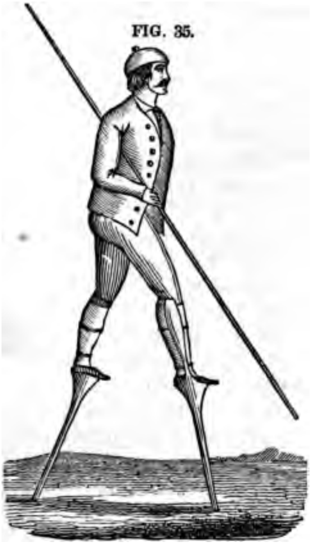
228. *Illustration by Trees.*—No form, under which matter exists, escapes the general law of gravity, and hence vegetables, as well as animals, are formed with reference to the position of this center, in respect to the base.

It is interesting, in reference to this circumstance, to observe how exactly the tall trees of the forest conform to this law.

The pine, which grows a hundred feet high, shoots up with as much exactness, with respect to keeping its center of gravity within the base, as though it had been directed by the plumb-line of a master builder. Its limbs toward the top are sent off in conformity to the same law; each one growing in respect to the other, so as to preserve a due balance between the whole.

229. Shepherds of Landes.—Men, as already noticed, by practice in the art of balancing, perform feats which are wonderful to all beholders. The shepherds of Landes, in the south of France, are perhaps the only people who apply this art to the common business of life. These men walk on stilts from four to five feet high; and their children, when quite young, who are intended to take the places of their fathers as shepherds, are taught this art in order to qualify them for business.

FIG. 35.



Shepherd of Landes.

To strangers, passing their district, these men cut a figure at once ludicrous and surprising. *Fig.* 35. But it is for their own convenience that this singular custom has been adopted, for by this means the feet are kept out of the water which

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227. In what does the art of balancing, or walking on a rope, consist? 228. What is observed in the growth of the trees of the forest, in respect to the laws of gravity? 229. What principle is involved in Fig. 35.

covers their land in the winter, and from the heated sand in the summer. Besides these comforts, the sphere of vision over a flat country is materially increased by the elevation, so that the shepherd can see his flock at a much greater distance than from the ground.

By habit, it is said these men acquire the art of balancing themselves so perfectly as to run, jump, and dance on these stilts with perfect ease. They walk with surprising quickness, so that footmen have to do their best to keep up with them.

CENTER OF INERTIA, OR INACTIVITY.

230. *It will be remembered that inertia* (22) *is one of the inherent, or essential properties of matter, and that it is in consequence of this property, when bodies are at rest, that they never move without the application of force, and when once in motion, that they never cease moving without some external cause.* (27.)

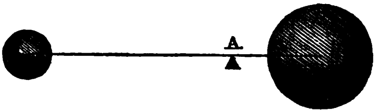
231. Now, inertia, though like gravity, it resides equally in every particle of matter, must have, like it, a center in each particular body, and this center is the same with that of gravity.

232. In a bar of iron, six feet long and two inches square, this center is just three feet from each end, or exactly in the middle. If, therefore, the bar is supported at this point, it will balance equally, and because there are equal weights on both ends, it will not fall.

Now suppose a bar should be raised by raising up the center of gravity, then the inertia of all its parts would be overcome equally with that of the middle. The center of gravity is, therefore, the center of inertia.

233. But, suppose the same bar of iron, whose inertia was overcome by raising the center, to have balls of different weights attached to its ends; then the center of inertia would no longer remain in the middle of the bar, but would be changed to the point A, *Fig.* 36, so that, to lift the whole, this point must be raised, instead of the middle, as before.

FIG. 36.



Center of Inertia.

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230. What effect does inertia exert on bodies at rest? What effect does it have on bodies in motion? 231. Is the center of inertia, and that of gravity, the same? 232. is the center of inertia in a body, or a system of bodies? 233. Why is the nertia changed, by fixing different weights to the ends of the iron bar?

EQUILIBRIUM.

234. *When two forces counteract, or balance each other, they are said to be in equilibrium.*

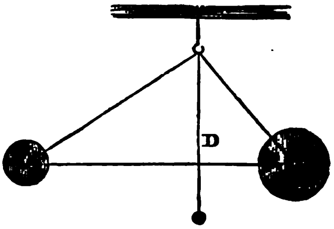
235. It is not necessary for this purpose that the weights opposed to each other should be equally heavy, for we have just seen that a small weight, placed at a distance from the center of inertia, will balance a large one placed near it. To produce equilibrium, it is only necessary that the weights on each side of the support should mutually counteract each other, or if set in motion, that their momenta should be equal.

236. A pair of scales are in equilibrium when the beam is in a horizontal position.

To produce equilibrium in solid bodies, therefore, it is only necessary to support the center of inertia, or gravity.

237. If a body, or several bodies, connected, be suspended by a string, as in *Fig.* 37, the point of support is always in a perpendicular line above the center of inertia. The plumb-line, D, cuts the bar connecting the two balls at this point. Were the two weights in this figure equal, it is evident that the hook, or point of support, must be in the middle of the string, to preserve the horizontal position.

FIG. 37.



Equilibrium.

238. When a man stands on his right foot, he keeps himself in equilibrium, by leaning to the right, so as to bring his center of gravity in a perpendicular line over the foot on which he stands.

CURVILINEAR, OR BENT MOTION.

239. *We have seen that a single force acting on a body,* (183,) *drives it straight forward, and that two forces acting crosswise, drive it midway between the two, or give it a diagonal direction,* (190.)

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234. What is meant by equilibrium? 235. To produce equilibrium, must the weights be equal? 236. When is a pair of scales in equilibrium? 237. When a body is suspended by a string, where must the support be with respect to the point of inertia? 239. What is meant by curvilinear motion?

Curvilinear motion differs from both these; the direction of the body being neither straight forward nor diagonal, but through a line which is curved.

This kind of motion may be in any direction; but when it is produced in part by gravity, its direction is always toward the earth.

239. A stream of water from an aperture in the side of a vessel, as it falls toward the ground, is an example of a curved line; and a body passing through such a line, is said to have *curvilinear* motion. Any body projected forward, as a cannon-ball, or rocket, falls to the earth in a curved line.

240. It is the action of gravity across the course of the stream, or the path of the ball, that bends it downward and makes it form a curve. The motion is, therefore, the result of two forces, that of projection, and that of gravity.

241. *In jets of water*, the shape of the curve will depend on the velocity of the stream. When the pressure of the water is great, the stream, near the vessel, is nearly horizontal, because its velocity is in proportion to the pressure. When a ball first leaves the cannon, it describes but a slight curve, because its projectile velocity is then greatest.

242. The curves described by jets of water under different degrees of pressure, are readily illustrated by tapping a tall vessel in several places, one above the other.

243. The action of gravity being always the same, the shape of the curve described must depend on the velocity of the moving body; but whether the projectile force be great or small, the moving body, if thrown horizontally, will reach the ground from the same height in the same time.

This, at first thought, would seem improbable; for, without consideration, most persons would assert, that, if two cannons were fired from the same spot at the same instant, and in the same direction, one of the balls falling half a mile, and the other a mile distant, that the ball which went to the greatest distance would take the most time in performing its journey.

244. But it must be remembered, that the projectile force does not in the least interfere with the force of gravity. A ball

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239. What are examples of this kind of motion? 240. What two forces produce this motion? 241. On what does the shape of the curve depend? 242. How are the curves described by jets of water illustrated? 243. What difference is there in respect to the time taken by a body to reach the ground, whether the curve be great or small? 244. Why do bodies, forming different curves from the same height, reach the ground at the same time? Suppose two balls, one flying at the rate of a thousand, and the other at the rate of a hundred feet per second, which would descend most ng the second?

flying horizontally, at the rate of a thousand feet per second, is attracted downward with precisely the same force as one flying only a hundred feet per second, and must, therefore, descend the same distance in the same time.

245. The distance to which a ball will go, depends on the force of impulse given it the first instant, and, consequently, on its projectile velocity. If it moves slowly, the distance will be short; if more rapidly, the space passed over will be greater. It makes no difference, then, in respect to the descent of the ball, whether its projectile motion be fast or slow, or whether it moves forward at all.

246. *Falling of Cannon Balls.*—This may be shown by experiment. Suppose a cannon to be loaded with a ball, and placed on the top of a tower, at such a height from the ground, that it would take just four seconds for the ball to descend from it to the ground, if let fall perpendicularly. Now, suppose the cannon to be fired in an exact horizontal direction, and, at the same instant, the ball to be dropped toward the ground. They will both reach the ground at the same instant, provided its surface be a horizontal plane from the foot of the tower to the place where the projected ball strikes.

247. *Demonstration.*—This is demonstrated by *Fig.* 38, where A is the cannon from which the ball is to be fired, *a* the vertical line of the descending ball, A, B, 1, *a*, the parallelogram through which the ball passes during the first second.

Now the ball dropped in the vertical direction, will descend 16 feet the first second, increasing its velocity according to the law of falling bodies already explained. Meantime the projected ball passing through the diagonal of the upper parallelogram, will arrive at 1, while the other falls to *a*. During the next second the vertical ball will fall to *b*, while the other, in consequence of its projectile force, will pass through the diagonal of the parallelogram *b*, 2, C, A.

The same laws of descent being continued, it is obvious, that the two balls will reach *d*, 4 at the same instant.

248. From these principles it may be inferred, that the horizontal motion of a body through the air, does not interfere with its gravitating motion toward the earth, and, therefore,

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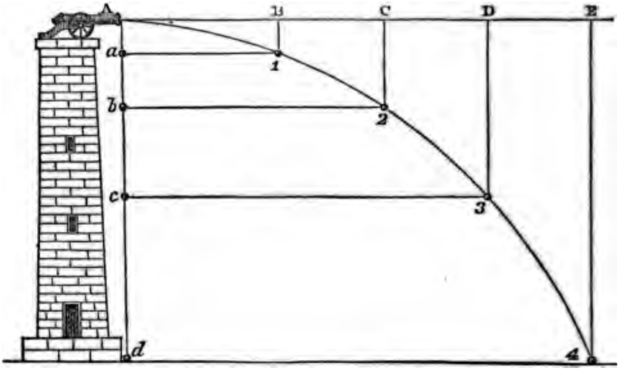
245. Does it make any difference in respect to the descent of the ball, whether it has a projectile motion or not? 246. Suppose, then, one ball be fired from a cannon, and another let fall from the same height at the same instant, would they both reach the ground at the same time? 247. Explain Fig. 38, showing the reason why the two balls will reach the ground at the same time. Why does the ball approach the earth more rapidly in the last part of the curve than in the first part? 248. What is the inference from these principles?

FIG. 38.



Path of a Cannon Ball.

that a rifle-ball, or any other body projected horizontally, will reach the ground in the same period of time as one that is let fall perpendicularly from the same height.

249. The two forces acting on bodies which fall through curved lines, are the same as the centrifugal and centripetal forces, already explained; the centrifugal, in case of the ball, being caused by the powder—the centripetal, being the action of gravity, (199.)

250. Now the space through which a cannon-ball, or any other body, can be thrown, depends on the velocity with which it is projected; for the attraction of gravitation, and the resistance of the air, acting perpetually, the *time* which a projectile can be kept in motion through the air is only a few moments.

Perpetual Revolution.—If the projectile be thrown from an elevated situation, it is plain that it would strike at a greater distance than if thrown on a level, because it would remain longer in the air. Every one knows that he can throw a stone to a greater distance when standing on a steep hill, than when standing on the plain below.

251. Suppose the circle, *Fig.* 39, to be the earth, and A, a high mountain on its surface. Suppose that this mountain

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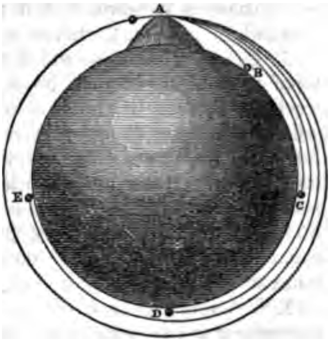
249. What is the force called which throws a ball forward? What is that called which brings it to the ground? 250. On what does the distance to which a projected body may be thrown, depend? Why does the distance depend on the velocity? 251. Suppose the velocity of a cannon-ball shot from a mountain 50 miles high to be ten times its usual rate, where would it stop?

reaches above the atmosphere, or is fifty miles high, then a cannon-ball might perhaps reach from A to B, a distance of eighty or a hundred miles, because the resistance of the atmosphere being out of the calculation, it would have nothing to contend with, except the attraction of gravitation. If, then, one degree of force, or velocity, would send it to B, another would send it to C; and if the force was increased three times, it would fall to D, and if four times, it would pass to E. If, now, we suppose the force to be about ten times greater than that with which a cannon-ball is projected, it would not fall to the earth at any of these points, but would continue its motion until it again came to the point A, the place from which it was first projected.

FIG. 39.



Perpetual Revolution of a Ball.

252. It would now be in equilibrium, the centrifugal force being just equal to that of gravity, and, therefore, it would perform another and another revolution, and so continue to revolve around the earth perpetually.

253. It is these two forces which retain the heavenly bodies in their orbits; and in the case we have supposed, our cannon-ball would become a little satellite, moving perpetually round the earth.

GUNNERY.

254. Law and Force of Projectiles.—Ever since the discovery of gunpowder, the laws of projectiles have been studied with attention, as being of importance in the art of war. Many learned and elaborate works have been published on the subject, but our limits will only admit the insertion of a few of the most important principles of Gunnery.

255. A projectile, as a bullet from a gun, unless it has a

Explain Fig. 39. 252. When would this ball be in equilibrium? Why would not the force of gravity ultimately bring this ball to the earth? 253. After the first revolution, if the two forces continued the same, would not the motion of the ball be perpetual? 254. Why are the laws of projectiles viewed important? 255. What two forces act on projectiles? What is the path of a projectile called?

vertical direction, is acted on by two forces, that of projection, which carries it forward, and that of gravity, which draws it downward. Its path, therefore, is a curve, called a *parabola*.

256. The distance to which the ball will fly, depends on the force of projection, since, if its direction is horizontal, its fall toward the earth by the force of gravity (250) will be the same, whether its velocity be great or small.

257. The resistance of the atmosphere, is the great impediment to the effects of projectile forces. Thus it has been demonstrated that a 24-lb. cannon-ball, discharged at an elevation of 45°, and at the velocity of 2000 feet per second, would, in vacuo, reach the horizon-distance of 125,000 feet, but the resistance of the air limits its range to 7,300 feet.

258. VELOCITY OF THE BALL.—There are several methods of computing the velocity of the ball, one of which is by means of the *Ballistic pendulum*. This is a thick, heavy block of wood, so suspended as to swing freely about on axis, and into this the ball is fired. The weight of the ball, and that of the block being known, the velocity is found, by the degrees of motion given to the pendulum, which is accurately measured by machinery.

259. *Recoil of the Gun.*—Another method of finding the velocity of the ball, is by means of the recoil of the gun. This method is founded on the supposition that the explosive force of the powder, communicates equal quantities of motion to the gun and ball, in opposite directions. Hence, by suspending the gun, loaded with weights, like a pendulum, the extent of its arc of vibration, will indicate the force of the charge, and by knowing the weights of the gun and ball, its velocity is indicated. By such means Dr. Hutton constructed the following table:—

POWDER.	VELOCITY PER SECOND.	DISTANCE.	TIME OF FLIGHT.
Ounces.	Feet.	Feet.	Seconds.
2	800	4100	9
4	1230	5100	12
8	1640	6000	14½
12	1680	6700	15½

260. Experiment shows that the velocity of the ball increases

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256. On what does the distance of a projectile depend? 257. What is said of atmospheric resistance? 258. What is the construction of the ballistic pendulum? 259. What is the other method of estimating the velocity of the ball?

with the charge, to a certain extent, which is peculiar to each gun, after which the increase diminishes the force, until the bore is quite full.

261. The greatest velocity of a ball known, is about 2000 feet per second, and this from a cannon. This velocity diminishes, soon after it leaves the gun.

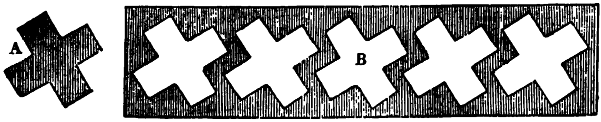
262. *Power and Destruction.*—The penetration of the ball is as the square of its velocity. Hence, when the object is merely to penetrate, as in the breaching of a fortification, the greatest velocity is given. But in naval combats, the utmost velocity is not the most injurious, the most destructive balls being such as merely pierce the ship's sides.

MANUFACTURE OF PERCUSSION CAPS.

263. The processes by which percussion caps are made at the establishment of Mr. McIntyre, in the city of Hartford, Ct., are as follow:—

264. *First.*—The copper is rolled to about the thickness of stout brown paper, and is then cut into strips three-fourths of an inch wide, and several yards long. The end of such a strip being placed between the rollers of a cutting and punching machine, invented for this purpose, the whole, without further attention, is cut into star-like pieces of the form and size represented by *Fig.* 40, A being the piece cut out, and B, the appearance of the strip of copper after the operation.

FIG. 40.



First shape of the Copper.

These pieces are instantly moved, by the same engine, under the punch, by which they are driven through a finely creased die, and are thus formed into caps which fall into a vessel below.

These stellate pieces, being struck by the punch in the center, the extremities are thus brought into contact, but not joined, so that the caps consist of four portions connected at the bottom, like the four quarters of an orange peel.

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260. How far does the velocity of the ball increase with that of the charge? 261. What is the greatest velocity of a ball? 262. What velocity of the ball is most destructive?

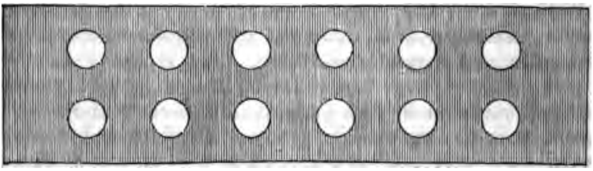
When the caps are exploded by the hammer, these quarters open and thus prevent the tearing of the metal which, if solid, would be apt to fly into fragments and thus endanger the eyes.

265. *Second.*—The caps are next placed in a revolving cylinder containing saw-dust, by which they are made clean and bright.

They are now ready to receive the *fulminating powder*, the explosion of which sets fire to the powder in the gun-barrel.

The caps are now placed, a handful at a time, on a sheet of iron, three feet long, eight inches wide, and the fourth of an inch thick, pierced with holes a quarter of an inch apart, as shown by *Fig.* 41. This being placed in a horizontal position, and shaken, the caps find their way into the apertures, with their open ends up, in a manner that is quite surprising.

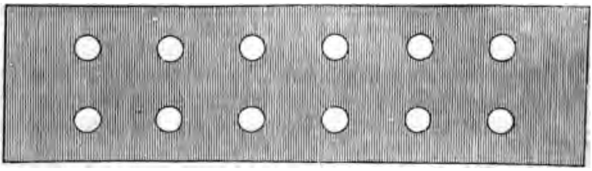
FIG. 41.



Mode of Placing the Caps for Filling.

266. *Third.*—A piece of brass plate, of the exact size of that containing the caps, is pierced with apertures to correspond with each and every cap, but smaller in size, as shown by *Fig.* 42.

FIG. 42.



Mode of Filling.

This plate, being about the sixth of an inch thick, is laid on a smooth surface, and the fulminating compound, a little moistened by gum-water, is rubbed into the apertures with the hand, re it adheres, that remaining on the surface being rubbed off.

267. *Fourth.*—This brass plate, being laid on that containing the caps, each aperture corresponding to a cap, the powder, by means of a brush, is made to fall into the caps.

268. *Fifth.*—The caps are now charged with the powder, in a loose state, and requires a gentle pressure to fix it in its place.

This is done by placing the plate, containing them, as above described, under rows of punches, which are worked with a little cam engine, and by which the punches are lifted, while the plate is moved forward, by means of a click and notches, so as to correspond exactly with the fall of the punches, by the pressure of which, the powder is fixed in its place.

269. *Sixth.*—The best caps are varnished, in order to protect them from moisture. It being the powder only which requires this protection, in France it is done with a little brush on each cap held in the fingers. But Mr. McIntyre has invented a much more expeditious way, and which insures the same quantity in each cap.

This is done by a small machine, consisting of two cams; a click working in horizontal notches, and a crank, by which the whole is moved. On the platform or bed of this, is laid the plate, *Fig.* 41, containing the caps, (268,) and on working the machine, two dozen blunt metallic points are alternately dipped into a little trough containing copal varnish, and then into the caps, these being moved by the click, to correspond with the revolution of the cams by which the motions of these points are produced. In this way hundreds of caps are varnished in a few minutes.

270. *Seventh.*—The edges of the best caps are polished, one at a time, by holding them with pliers for a second on a spindle of steel, revolving a thousand times a minute, the point of which enters the cap, the edge rubbing against a shoulder, by which the work is done.

With two engines, as above described, the proprietor estimates the number of caps made per day, to be about 100,000, a market being always ready for all he can make.

RESULTANT MOTION.

271. *Resultant motion consists in the operation of two, or more, forces, the joint action of which, results in unity of effect.*

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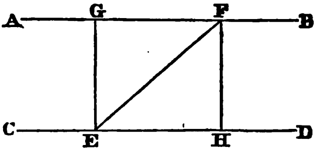
271. What is meant by resultant motion? Suppose two boats sailing at the same rate and in the same direction, if an apple be tossed from one to the other, what will be its direction in respect to the boats?

Suppose two men to be sailing in two boats, each at the rate of four miles an hour, at a short distance opposite to each other, and suppose as they are sailing along in this manner, one of the men throws the other an apple. In respect to the boats, the apple would pass directly across from one to the other, that is, its line of direction would be at right-angles with the sides of the boats. But its actual line through the air would be oblique, or diagonal, in respect to the sides of the boats, because, in passing from boat to boat, it is impelled by two forces, viz., the force of the motion of the boat forward, and the force by which it is thrown by the hand across this motion.

FIG. 43.



Diagonal Motion.

272. This diagonal motion of the apple is called the *resultant*, or the resulting motion, because it is the effect or result of two motions resolved into one. Perhaps this will be more clear by *Fig.* 43, where A B, and C D, are supposed to be the sides of the two boats, and the line E F, that of the apple. Now the apple, when thrown, has a motion with the boat at the rate of four miles an hour, from C toward D, and this motion is supposed to continue just as though it had remained in the boat.

273. Had it remained in the boat during the time it was passing from E to F, it would have passed from E to H. But we suppose it to have been thrown at the rate of eight miles an hour, in the direction toward G; and if the boats are moving south, and the apple thrown toward the east, it would pass in the same time twice as far toward the east as it did toward the south. Therefore, in respect to the boats the apple would pass at right-angles from the side of one to that of the other, because they are both in motion. But in respect to a right line, drawn from the point where the apple was thrown, and a parallel line with this, drawn from the point where it strikes the other boat, the line of the apple would be oblique. This will be clear, when we consider that, when the apple is thrown, the boats are at the points E and G, and that when it strikes, they are at H and F, these two points being opposite to each other.

What would be its line through the air in respect to the boats? 272. What is this kind of motion called? Why is it called resultant motion? Explain Fig. 43. 273. Why would the line of the apple be actually at right-angles in respect to the boats, but oblique in respect to parallel lines drawn from where it was thrown and where it struck? How is this further illustrated?

The line E F, through which the apple is thrown, is called the diagonal of a parallelogram, as already explained under compound motion.

274. On the above principle, if two ships, during a battle, are sailing before the wind at equal rates, the aim of the gunners will be exactly the same as though they stood still; whereas, if the gunner fires from a ship standing still, at another under sail, he takes his aim forward of the mark he intends to hit, because the ship would pass a little forward while the ball is going to her.

275. And so, on the contrary, if a ship in motion fires at another standing still, the aim must be behind the mark, because, as the motion of the ball partakes of that of the ship, it will strike forward at the point aimed at.

276. For the same reason, if a ball be dropped from the topmast of a ship under sail, it partakes of the motion of the ship forward, and will fall in a line with the mast, and strike the same point on the deck as though the ship stood still.

If a man upon the full run drops a bullet before him from the height of his head, he can not run so fast as to overtake it before it reaches the ground.

It is on this principle, that if a cannon-ball be shot up vertically from the earth, it will fall back to the same point; for, although the earth moves forward while the ball is in the air, yet, as it carries this motion with it, so the ball moves forward, also, in an equal degree, and, therefore, comes down at the same place.

HOROLOGY.

277. *This term, derived from the Greek, means, to indicate the hour. It is the science of time-keeping.*

278. For this purpose, a great variety of instruments have been invented, by some of which, time was measured by the dropping of water, as in the *clepsydra*, or water-clock, in others, by the running of sand, as in the hour-glass, or by the revolution of the sun, by means of the *gnomon*, or sun-dial. But these ancient methods have given place to the modern invention of clocks, regulated by the *pendulum*, and watches, regulated by a *balance-wheel.*

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274. When the ships are in equal motion, where does the gunner take his aim? Why does he aim forward of the mark when the other ship is in motion? 275. If a ship in motion fires at one standing still, where must be the aim? Why, in this case, must the aim be behind the mark? 276. What other illustrations are given of resultant motion? 277. What is the meaning of horology? 278. What were the ancient methods of keeping time?

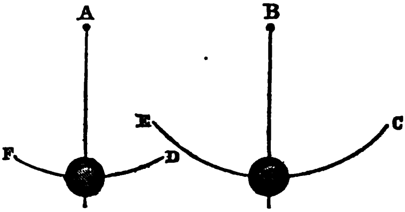
PENDULUM.

279. *A pendulum is a heavy body, such as a piece of brass or lead, suspended by a wire or cord, so as to swing backward and forward.*

When a pendulum swings, it is said to *vibrate;* and that part of a circle through which it vibrates, is called its *arc.*

280. The times of the vibration of a pendulum are very nearly equal, whether it pass through a greater or less part of its arc.

FIG. 44.



Pendulum.

Suppose A and B, *Fig.* 44, to be two pendulums of equal length, and suppose the weights of each are carried, the one to C, and the other to D, and both let fall at the same instant; their vibrations would be equal in respect to time, the one passing through its arc from C to E, and so back again in the same time that the other passes from D to F, and back again.

281. The reason of this appears to be, that when the pendulum is raised high, the action of gravity draws it more directly downward, and it therefore acquires in falling a greater comparative velocity than is proportioned to the trifling difference of height.

282. *Common Clock.*—In the common clock, the pendulum is connected with wheel-work, to regulate the motion of the hands, and with weights, by which the whole is moved. The vibrations of the pendulum are numbered by a wheel or escapement, having thirty teeth, which revolves once in a minute. Each tooth, therefore, answers to one vibration of the pendulum, and the wheel moves forward one tooth in a second, Thus the second-hand revolves once in every sixty beats of the pendulum; and, as these beats are seconds, it goes round once in a minute. By the pendulum the whole machine is regulated, for the clock goes faster or slower, according to its num-

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279. What is a pendulum? 280. What is meant by the vibration of a pendulum? What is that part of a circle called through which it swings? 281. Why does the pendulum vibrate in equal time whether it goes through a small or large part of its arc? 282. Describe the common clock. How many vibrations has the pendulum in a minute?

ber of vibrations in a given time. The number of vibrations which a pendulum makes in a given time depends upon its length, because a long pendulum does not perform its journey to and from the corresponding points of its arc so soon as a short one.

283. As the motion of the clock is regulated entirely by the pendulum, and as the number of vibrations are as its length, the least variation in this respect will alter its rate of going. To beat seconds, its length must be about thirty-nine inches. In the common clock, the length is regulated by a screw, which raises and lowers the weight. But as the rod to which the weight is attached is subject to variations of length, in consequence of the change of the seasons, being contracted by cold and lengthened by heat, the common clock goes faster in winter than in summer.

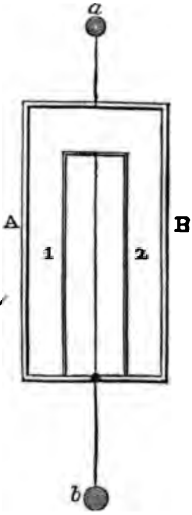
In the small clocks of the present day, the pendulum oscillates twice and sometimes more in a second, and consequently the escapement must have 60 or more teeth, the second-hand performing two revolutions in a minute.

The length of a pendulum beating two seconds is the square of that beating seconds. If the length of the seconds pendulum be 39¼ inches, then that beating two seconds will be about 13 feet.

A pendulum beating half seconds is in length, as the square root of that beating seconds, or about 10 inches long.

284. *Gridiron Pendulum.*—Various means have been contrived to counteract the effects of these changes, so that the pendulum may continue the same length the whole year. Among inventions for this purpose, the *gridiron* pendulum is considered among the best. It is so called, because it consists of several rods of different metals connected together at each end.

FIG. 45.



Gridiron Pendulum.

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283. On what depends the number of vibrations which a pendulum makes in a given time? What is the medium length of the pendulum beating seconds? Why does a common clock go faster in winter than in summer? What is necessary in respect to the pendulum, to make the clock go true the year round? 284. What is the principle on which the gridiron pendulum is constructed?

285. The principle on which this pendulum is constructed is derived from the fact that some metals dilate more by the same degrees of heat than others. Thus, brass will dilate about twice as much by heat, and, consequently, contract twice as much by cold, as steel. If, then, these differences could be made to counteract each other mutually, given points at each end of a system of such rods would remain stationary the year round, and thus the clock would go at the same rate in all climates, and during all seasons.

286. Suppose, then, steel bars A B, are firmly fixed to cross bars at each end, as seen by *Fig.* 45, and that on the lower cross bar, the brass rods 1 2, are also fixed, then the steel bars can expand only downward, and the brass ones, only upward. Now as the pendulum rod passes through the lower cross bar, and is fixed to the upper cross piece of the brass rods, it will be seen that the elongation of the two metals by heat mutually counteract each other, and therefore that the point of suspension, *a*, and the pendulum weight, *b*, will always remain at the same distance from each other. It is found by experiment that the expansion of brass to that of steel is in the proportion of 100 to 61.

287. *Gravity varies the Vibrations.*—As it is the force of gravity which draws the weight of the pendulum from the highest point of its arc downward, and as this force increases or diminishes as bodies approach toward the center of the earth, or recede from it, so the pendulum will vibrate faster or slower in proportion as this attraction is stronger or weaker.

288. Now it is known that the earth at the equator rises higher from its center than it does at the poles, for toward the poles it is flattened. The pendulum, therefore, being more strongly attracted at the poles than at the equator, vibrates more rapidly. For this reason, a clock that would keep exact time at the equator would gain time at the poles, for the rate at which a clock goes depends on the number of vibrations its pendulum makes. Therefore, pendulums, in order to beat seconds, must be shorter at the equator, and longer at the poles.

For the same reason, a clock which keeps exact time at the foot of a high mountain, would move slower on its top.

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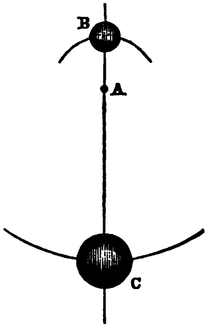
285. What are the metals of which this instrument is made? 286. Explain Fig. 45, and give the reason why the length of the pendulum will not change by the variations of temperature. 287. What is the downward force which makes the pendulum vibrate? Explain the reason why the same clock would go faster at the poles, and slower at the equator. 288. How can a clock which goes true at the equator be made to go true at the poles? Will a clock keep equal time at the foot and on the top of a high mountain? Why will it not?

289. **Metronome.**—There is a short pendulum, used by musicians for marking time, which may be made to vibrate fast or slow, as occasion requires. This little instrument is called a *metronome*, and besides the pendulum, consists of several wheels, and a spiral spring, by which the whole is moved. This pendulum is only ten or twelve inches long, and instead of being suspended by the end, like other pendulums, the rod is prolonged above the point of suspension, and there is a ball placed near the upper, as well as at the lower extremity.

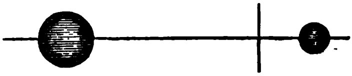
290. This arrangement will be understood by *Fig.* 46, where A is the axis of suspension, B the upper ball, and C the lower one. Now, when this pendulum vibrates from the point A, the upper ball constantly retards the motion of the lower one, by in part counterbalancing its weight, and thus preventing its full velocity downward.

FIG. 46.



291. Perhaps this will be more apparent, by placing the pendulum, *Fig.* 47, for a moment on its side, and across a bar, at the point of suspension. In this position, it will be seen that the little ball would prevent the large one from falling with its full weight, since, were it moved to a certain distance from the point of suspension, it would balance the large one so that it would not descend at all. It is plain, therefore, that the comparative velocity of the large ball will be in proportion as the small one is moved to a greater or less distance from the point of suspension. The metronome is so constructed, the little ball being made to move up and down on the rod at pleasure, that its vibrations are made to beat the time of a quick or slow tune, as occasion requires.

FIG. 47.



Metronome.

By this arrangement, the instrument is made to vibrate every two seconds, or every half, or quarter of a second, at pleasure. *Metronome* means *time measurer.*

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289. What is the metronome? How does this pendulum differ from the common pendulums? 290. Explain Fig. 46. 291. How does the upper ball retard the motion of the lower one? How is the metronome made to go faster or slower, at pleasure?

CHAPTER IV.

MECHANICS.

292. *Mechanics is a science which investigates the laws and effects of force and motion.*

293. The practical object of this science is, to teach the best modes of overcoming resistances by means of mechanical powers, and to apply motion to useful purposes, by means of machinery.

294. A *machine* is any instrument by which power, motion, or velocity, is applied or regulated.

295. A machine may be very simple, or exceedingly complex. Thus, a pin is a machine for fastening clothes, and a steam-engine is a machine for propelling mills and boats.

As machines are constructed for a vast variety of purposes, their forms, powers, and kinds of movement, must depend on their intended uses.

Several considerations ought to precede the actual construction of a new or untried machine; for if it does not answer the purpose intended, it is commonly a total loss to the builder.

Many a man, on attempting to apply an old principle to a new purpose, or to invent a new machine for an old purpose, has been sorely disappointed, having found, when too late, that his time and money had been thrown away, for want of proper reflection, or requisite knowledge.

If a man, for instance, thinks of constructing a machine for raising a ship, he ought to take into consideration the *inertia* or *weight*, to be moved—the *force* to be applied—the *strength* of the materials, and the *space* or situation he has to work in. For, if the force applied, or the strength of the materials be insufficient, his machine is obviously useless; and if the force and strength be ample, but the space be wanting, the same result must follow.

If he intends his machine for twisting the fibers of flexible substances into threads, he may find no difficulty in respect to power, strength of materials, or space to work in, but if the

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292. What is mechanics? 293. What is the object of this science? 294. What is a machine? 295. Mention one of the most simple, and one of the most complex of machines.

velocity, *direction*, and kind of motion he obtains, be not applicable to the work intended, he still loses his labor.

Thousands of machines have been constructed, which, so far as regarded the skill of the workmen, the ingenuity of the contriver, and the construction of the individual parts, were models of art and beauty; and, so far as could be seen without trial, admirably adapted to the intended purpose. But on putting them to actual use, it has too often been found, that their only imperfection consisted in a stubborn refusal to do any part of the work intended.

Now, a thorough knowledge of the laws of motion, and the principles of mechanics, would, in many instances, at least, have prevented all this loss of labor and money, and spared him so much vexation and chagrin, by showing the projector that his machine would not answer the intended purpose.

The importance of this kind of knowledge is therefore obvious, and it is hoped will become more so as we proceed.

DEFINITIONS.

296. In mechanics, as well as in other sciences, there are words which must be explained, either because they are common words used in a peculiar sense, or because they are terms of art, not in common use. All technical terms will be as much as possible avoided, but still there are a few, which it is necessary here to explain.

297. *Force* is the means by which bodies are set in motion, kept in motion, and when moving, are brought to rest. The force of gunpowder sets the ball in motion, and keeps it moving, until the force of the resisting air, and the force of gravity, bring it to rest.

298. *Power* is the means by which the machine is moved, and the force gained. Thus we have horse-power, water-power, and the power of weights.

299. *Weight* is the resistance, or the thing to be moved by the force of the power. Thus the stone is the weight to be moved by the force of the lever or bar.

300. *Fulcrum*, or prop, is the point on which a thing is supported, and about which it has more or less motion. In raising a stone, the thing on which the lever rests, is the fulcrum.

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297. What is meant by force in mechanics? 298. What is meant by power? 299. What is understood by weight? 300. What is the fulcrum? 301. Are the mechanical powers numerous, or only few in number?

301. In mechanics, there are a few simple machines called the *mechanical powers*, and however mixed, or complex, a combination of machinery may be, it consists only of these few individual powers.

We shall not here burden the memory of the pupil with the names of these powers, of the nature of which he is at present supposed to know nothing, but shall explain the action and use of each in its turn, and then sum up the whole for his accommodation.

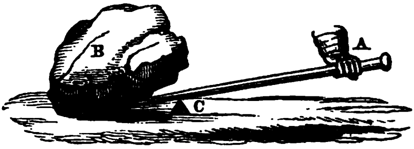
THE LEVER.

302. *Any rod, or bar, which is used in raising a weight, or surmounting a resistance, by being placed on a fulcrum, or prop, becomes a lever. Levers are simple and compound.*

303. *Simple levers* are of three kinds, namely: first, where the fulcrum is between the power and the weight; second, where the weight is between the fulcrum and the power; third, where the power is between the fulcrum and the weight.

304. *First Kind.*—The first kind is represented by *Fig.* 48, being a straight rod of iron, called a *crowbar*, in common use for raising rocks and other heavy bodies. The stone, B, is the *weight*, A the *lever*, and C the *fulcrum*; the *power* being the hand of a man applied at A.

FIG. 48.



Simple Lever.

It will be observed, that by this arrangement the application of a small power may be used to overcome a great resistance.

305. The force to be obtained by the lever, depends on its length, together with the power applied, and the distance of the weight and power from the fulcrum.

306. Suppose, *Fig.* 49, that A is the lever, B the fulcrum, D the weight to be raised, and C the power. Let D be considered three times as heavy as C, and the fulcrum three times as far from C as it is from D; then the weight and power will exactly balance each other. Thus, if the bar be four feet long,

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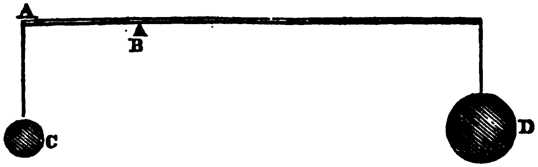
302. What is a lever? 303. What are the three kinds of simple levers? 304. What is the simplest of all mechanical powers? Explain Fig. 48. Which is the weight? Where is the fulcrum? Where is the power applied? What is the power in this case? 305. On what does the force to be obtained by the lever depend? 306. Suppose a lever four feet long, and the fulcrum one foot from the end, what number of pounds will balance each other at the ends?

FIG. 49.

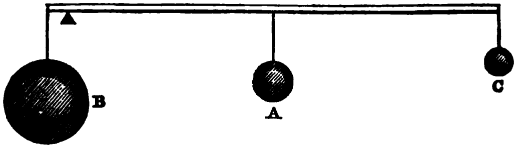


Lever—Unequal Arms.

and the fulcrum three feet from the end, then three pounds on the long arm will weigh just as much as nine pounds on the short arm, and these proportions will be found the same in all cases.

307. When two weights balance each other, the fulcrum is always at the center of gravity between them, and therefore, to make a small weight raise a large one, the fulcrum must be placed as near as possible to the large one, since the greater the distance *from the fulcrum the small weight* or power is placed, the greater will be its force.

FIG. 50.



Lever—Double Weights.

308. Suppose the weight B, *Fig.* 50, to be sixteen pounds, and suppose the fulcrum to be placed so near it, as to be raised by the power A, of four pounds hanging equally distant from the fulcrum and the end of the lever. If now the power A be removed, and another of two pounds, C, be placed at the end of the lever, its force will be just equal to A, placed at the middle of the lever.

309. But let the fulcrum be moved along to the middle of the lever, with the weight of sixteen pounds still suspended to it, it would then take another weight of sixteen pounds, instead of two pounds, to balance it, *Fig.* 51.

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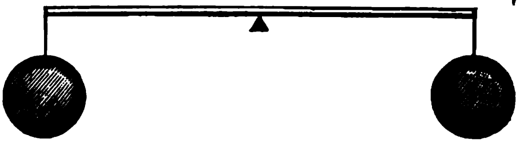
307. When weights balance each other, at what point between them must the fulcrum be? 308. Suppose a weight of 16 pounds on the short arm of a lever is counterbalanced by 4 pounds in the middle of the long arm, what power would balance this weight at the end of the lever? 309. Suppose the fulcrum to be mo middle of the lever, what power would then be equal to 16 pounds?

FIG. 51.



Lever—Equal Arms.

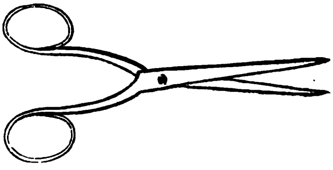
Thus, the power which would balance sixteen pounds, when the fulcrum is in one place, must be exchanged for another power weighing eight times as much, when the fulcrum is in another place.

310. From these investigations, we may draw the following general truth, or proposition, concerning the lever: "*That the force of the lever increases in proportion to the distance of the power from the fulcrum, and diminishes in proportion as the distance of the weight from the fulcrum increases.*"

311. From this proposition, may be drawn the following rule, by which the exact proportions between the weight or resistance, and the power, may be found. *Multiply the weight by its distance from the fulcrum; then multiply the power by its distance from the same point, and if the products are equal, the weight and the power will balance each other.*

312. Suppose a weight of 100 pounds on the short arm of a lever, 8 inches from the fulcrum, then another weight, or power, of 8 pounds, would be equal to this, at the distance of 100 inches from the fulcrum; because 8 multiplied by 100 is equal to 800; and 100 multiplied by 8 is equal to 800, and thus they would mutually counteract each other.

FIG. 52.



Two Levers.

313. Many instruments in common use are on the principle of this kind of lever. Scissors, *Fig.* 52, consist of two levers, the rivet being the *fulcrum* for both. The fingers are the *power*, and the cloth to be cut, the *resistance* to be overcome.

Pincers, *forceps*, and *sugar-cutters*, are examples of this kind of lever.

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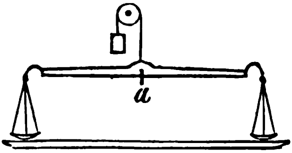
310. What is the general proposition drawn from these results? 311. What is the rule for finding the proportions between the weight and power? 312. Give an illustration of this rule. 313. What instruments operate on the principle of this lever?

314. A common *scale-beam*, used for weighing, is a lever, suspended at the center of gravity, so that the two arms balance each other. Hence the machine is called a *balance*. The fulcrum, or what is called the *pivot*, is sharpened, like a wedge, and made of hardened steel, so as much as possible to avoid friction.

FIG. 53.

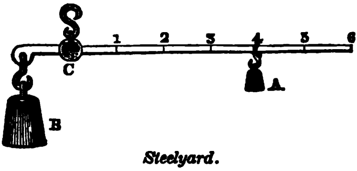


Common Scales.

315. A dish is suspended by cords to each end or arm of the lever, for the purpose of holding the articles to be weighed. When the whole is suspended at the point *a*, *Fig.* 53, the beam or lever ought to remain in a horizontal position, one of its ends being exactly as high as the other. If the weights in the two dishes are equal, and the support exactly in the center, they will always hang as represented in the figure.

316. A very slight variation of the point of support toward one end of the lever, will make a difference in the weights employed to balance each other. In weighing a pound of sugar, with a scale-beam of eight inches long, if the point of support is half an inch too near the weight, the buyer would be cheated nearly one ounce, and consequently nearly one pound in every sixteen pounds. This fraud might instantly be detected by changing the places of the sugar and weight, for then the difference would be quite material, since the sugar would then seem to want twice as much additional weight as it did really want.

FIG. 54.



Steelyard.

317. The *steelyard* differs from the balance, in having its support near one end, instead of in the middle, and also in having the weights suspended by hooks, instead of being placed in a dish.

If we suppose the beam to be 7 inches long, and the hook, C, *Fig.* 54, to be one inch from the end, then the pound weight, A, will require an additional pound at B, for every inch it is

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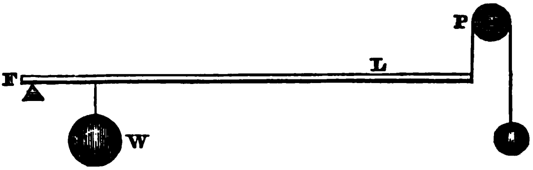
314. In the common scale-beam, where is the fulcrum? 315. In what position ought the scale-beam to hang? 316. How may a fraudulent scale-beam be made? How may the cheat be detected? 317. How does the steelyard differ from the balance?

moved from it. This, however, supposes that the bar will balance itself, before any weights are attached to it.

FIG. 55.



Lever of the Second Kind.

318. *Second Kind.*—The second kind of lever is represented by *Fig.* 55, where W is the weight, L the lever, F the fulcrum, and P a pulley, over which a string is thrown, and a weight suspended, as the power. In the common use of a lever of the first kind, the force is gained by bearing down the long arm, which is called *prying.* In the second kind, the force is gained by carrying the long arm in a contrary direction, or upward, and this is called *lifting.*

319. Levers of the second kind are not so common as the first, but are frequently used for certain purposes. The oars of a boat are examples of the second kind. The water against which the blade of the oar pushes, is the fulcrum, the boat is the weight to be moved, and the hands of the man, the power.

320. Two men carrying a load between them on a pole, is also an example of this kind of lever. Each man acts as the power in moving the weight, and at the same time each becomes the fulcrum in respect to the other.

If the weight happens to slide on the pole, the man toward whom it goes has to bear more of it in proportion as its distance from him is less than before.

321. A load at A, *Fig.* 56, is borne equally by the two men, being equally distant from each other; but at B, three quarters of its weight would be on the man at that end, because three quarters of the length of the lever would be on the side of the other man.

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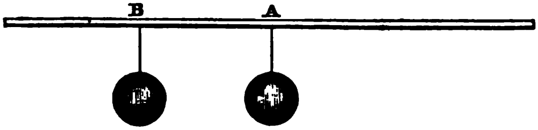
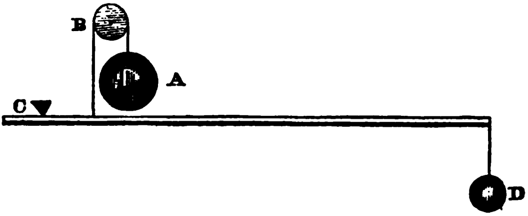
318. In the first kind of lever, where is the fulcrum, in respect to the weight and power? In the second kind, where is the fulcrum, in respect to the weight and power? What is the action of the first kind called? What is the action of the second kind called? 319. Give examples of the second kind of lever. 320. In rowing a boat, what is the fulcrum, what the weight, and what the power? 321. What other illustrations of this principle are given?

FIG. 56.



Lever—Unequal Arms.

FIG. 57



Lever of the Third Kind.

322. *Third Kind.*—In the third and last kind of lever, the weight is placed at one end, the fulcrum at the other end, and the power between them, or the hand, is between the fulcrum and the weight.

This is represented by *Fig.* 57, where C is the fulcrum, A the power, suspended over the pulley B, and D is the weight to be raised.

323. This kind of lever works to great disadvantage, since the power must be greater than the weight. It is therefore seldom used, except in cases where velocity and not force is required. In raising a ladder from the ground to the roof of a house, men are obliged sometimes to make use of this principle, and the great difficulty of doing so, illustrates the mechanical disadvantage of this kind of lever.

We have now described the three kinds of levers, and, we hope, have made the manner in which each kind acts plain, by illustrations. But to make the difference between them still more obvious, and to avoid all confusion, we will here compare them together.

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322. In the third kind of lever where are the respective places of the weight, power, and fulcrum? 323. What is the disadvantage of this kind of lever? Give an example of the use of the third kind of lever?

CHAPTER IV.

MECHANICS.

292. *Mechanics is a science which investigates the laws and effects of force and motion.*

293. The practical object of this science is, to teach the best modes of overcoming resistances by means of mechanical powers, and to apply motion to useful purposes, by means of machinery.

294. A *machine* is any instrument by which power, motion, or velocity, is applied or regulated.

295. A machine may be very simple, or exceedingly complex. Thus, a pin is a machine for fastening clothes, and a steam-engine is a machine for propelling mills and boats.

As machines are constructed for a vast variety of purposes, their forms, powers, and kinds of movement, must depend on their intended uses.

Several considerations ought to precede the actual construction of a new or untried machine; for if it does not answer the purpose intended, it is commonly a total loss to the builder.

Many a man, on attempting to apply an old principle to a new purpose, or to invent a new machine for an old purpose, has been sorely disappointed, having found, when too late, that his time and money had been thrown away, for want of proper reflection, or requisite knowledge.

If a man, for instance, thinks of constructing a machine for raising a ship, he ought to take into consideration the *inertia* or *weight*, to be moved—the *force* to be applied—the *strength* of the materials, and the *space* or situation he has to work in. For, if the force applied, or the strength of the materials be insufficient, his machine is obviously useless; and if the force and strength be ample, but the space be wanting, the same result must follow.

If he intends his machine for twisting the fibers of flexible substances into threads, he may find no difficulty in respect to power, strength of materials, or space to work in, but if the

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292. What is mechanics? 293. What is the object of this science? 294. What is a machine? 295. Mention one of the most simple, and one of the most complex of machines.

velocity, *direction*, and kind of motion he obtains, be not applicable to the work intended, he still loses his labor.

Thousands of machines have been constructed, which, so far as regarded the skill of the workmen, the ingenuity of the contriver, and the construction of the individual parts, were models of art and beauty; and, so far as could be seen without trial, admirably adapted to the intended purpose. But on putting them to actual use, it has too often been found, that their only imperfection consisted in a stubborn refusal to do any part of the work intended.

Now, a thorough knowledge of the laws of motion, and the principles of mechanics, would, in many instances, at least, have prevented all this loss of labor and money, and spared him so much vexation and chagrin, by showing the projector that his machine would not answer the intended purpose.

The importance of this kind of knowledge is therefore obvious, and it is hoped will become more so as we proceed.

DEFINITIONS.

296. In mechanics, as well as in other sciences, there are words which must be explained, either because they are common words used in a peculiar sense, or because they are terms of art, not in common use. All technical terms will be as much as possible avoided, but still there are a few, which it is necessary here to explain.

297. *Force* is the means by which bodies are set in motion, kept in motion, and when moving, are brought to rest. The force of gunpowder sets the ball in motion, and keeps it moving, until the force of the resisting air, and the force of gravity, bring it to rest.

298. *Power* is the means by which the machine is moved, and the force gained. Thus we have horse-power, water-power, and the power of weights.

299. *Weight* is the resistance, or the thing to be moved by the force of the power. Thus the stone is the weight to be moved by the force of the lever or bar.

300. *Fulcrum*, or prop, is the point on which a thing is supported, and about which it has more or less motion. In raising a stone, the thing on which the lever rests, is the fulcrum.

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297. What is meant by force in mechanics? 298. What is meant by power? 299. What is understood by weight? 300. What is the fulcrum? 301. Are the mechanical powers numerous, or only few in number?

301. In mechanics, there are a few simple machines called the *mechanical powers*, and however mixed, or complex, a combination of machinery may be, it consists only of these few individual powers.

We shall not here burden the memory of the pupil with the names of these powers, of the nature of which he is at present supposed to know nothing, but shall explain the action and use of each in its turn, and then sum up the whole for his accommodation.

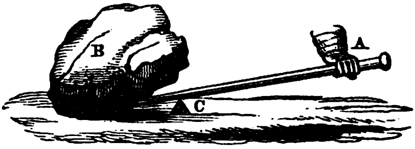
THE LEVER.

302. *Any rod, or bar, which is used in raising a weight, or surmounting a resistance, by being placed on a fulcrum, or prop, becomes a lever. Levers are simple and compound.*

303. *Simple levers* are of three kinds, namely: first, where the fulcrum is between the power and the weight; second, where the weight is between the fulcrum and the power; third, where the power is between the fulcrum and the weight.

304. *First Kind.*—The first kind is represented by *Fig.* 48, being a straight rod of iron, called a *crowbar*, in common use for raising rocks and other heavy bodies. The stone, B, is the *weight*, A the *lever*, and C the *fulcrum;* the *power* being the hand of a man applied at A.

FIG. 48.



Simple Lever.

It will be observed, that by this arrangement the application of a small power may be used to overcome a great resistance.

305. The force to be obtained by the lever, depends on its length, together with the power applied, and the distance of the weight and power from the fulcrum.

306. Suppose, *Fig.* 49, that A is the lever, B the fulcrum, D the weight to be raised, and C the power. Let D be considered three times as heavy as C, and the fulcrum three times as far from C as it is from D; then the weight and power will exactly balance each other. Thus, if the bar be four feet long,

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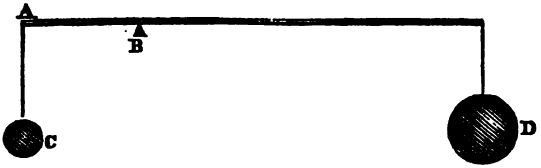
302. What is a lever? 303. What are the three kinds of simple levers? 304. What is the simplest of all mechanical powers? Explain Fig. 48. Which is the weight? Where is the fulcrum? Where is the power applied? What is the power in this case? 305. On what does the force to be obtained by the lever depend? 306. Suppose a lever four feet long, and the fulcrum one foot from the end, what number of pounds will balance each other at the ends?

FIG. 49.

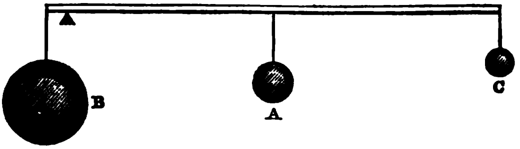


Lever—Unequal Arms.

and the fulcrum three feet from the end, then three pounds on the long arm will weigh just as much as nine pounds on the short arm, and these proportions will be found the same in all cases.

307. When two weights balance each other, the fulcrum is always at the center of gravity between them, and therefore, to make a small weight raise a large one, the fulcrum must be placed as near as possible to the large one, since the greater the distance *from the fulcrum the small weight* or power is placed, the greater will be its force.

FIG. 50.



Lever—Double Weights.

308. Suppose the weight B, *Fig.* 50, to be sixteen pounds, and suppose the fulcrum to be placed so near it, as to be raised by the power A, of four pounds hanging equally distant from the fulcrum and the end of the lever. If now the power A be removed, and another of two pounds, C, be placed at the end of the lever, its force will be just equal to A, placed at the middle of the lever.

309. But let the fulcrum be moved along to the middle of the lever, with the weight of sixteen pounds still suspended to it, it would then take another weight of sixteen pounds, instead of two pounds, to balance it, *Fig.* 51.

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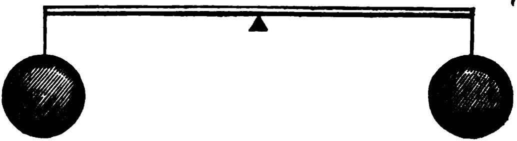
307. When weights balance each other, at what point between them must the fulcrum be? **308.** Suppose a weight of 16 pounds on the short arm of a lever is counterbalanced by 4 pounds in the middle of the long arm, what power would balance this weight at the end of the lever? **309.** Suppose the fulcrum to be moved to the middle of the lever, what power would then be equal to 16 pounds?

FIG. 51.



Lever—Equal Arms.

Thus, the power which would balance sixteen pounds, when the fulcrum is in one place, must be exchanged for another power weighing eight times as much, when the fulcrum is in another place.

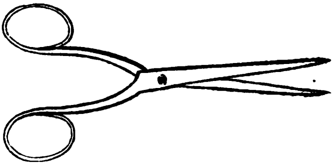
310. From these investigations, we may draw the following general truth, or proposition, concerning the lever: "*That the force of the lever increases in proportion to the distance of the power from the fulcrum, and diminishes in proportion as the distance of the weight from the fulcrum increases.*"

311. From this proposition, may be drawn the following rule, by which the exact proportions between the weight or resistance, and the power, may be found. *Multiply the weight by its distance from the fulcrum; then multiply the power by its distance from the same point, and if the products are equal, the weight and the power will balance each other.*

312. Suppose a weight of 100 pounds on the short arm of a lever, 8 inches from the fulcrum, then another weight, or power, of 8 pounds, would be equal to this, at the distance of 100 inches from the fulcrum; because 8 multiplied by 100 is equal to 800; and 100 multiplied by 8 is equal to 800, and thus they would mutually counteract each other.

313. Many instruments in common use are on the principle of this kind of lever. Scissors, *Fig.* 52, consist of two levers, the rivet being the *fulcrum* for both. The fingers are the *power*, and the cloth to be cut, the *resistance* to be overcome.

FIG. 52.



Two Levers.

Pincers, *forceps*, and *sugar-cutters*, are examples of this kind of lever.

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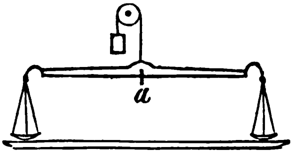
310. What is the general proposition drawn from these results? 311. What is the rule for finding the proportions between the weight and power? 312. Give an illustration of this rule. 313. What instruments operate on the principle of this lever?

314. A common *scale-beam*, used for weighing, is a lever, suspended at the center of gravity, so that the two arms balance each other. Hence the machine is called a *balance*. The fulcrum, or what is called the *pivot*, is sharpened, like a wedge, and made of hardened steel, so as much as possible to avoid friction.

FIG. 53.

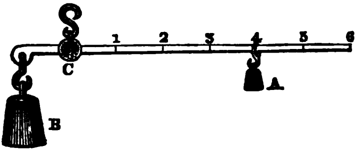


Common Scales.

315. A dish is suspended by cords to each end or arm of the lever, for the purpose of holding the articles to be weighed. When the whole is suspended at the point *a*, *Fig.* 53, the beam or lever ought to remain in a horizontal position, one of its ends being exactly as high as the other. If the weights in the two dishes are equal, and the support exactly in the center, they will always hang as represented in the figure.

316. A very slight variation of the point of support toward one end of the lever, will make a difference in the weights employed to balance each other. In weighing a pound of sugar, with a scale-beam of eight inches long, if the point of support is half an inch too near the weight, the buyer would be cheated nearly one ounce, and consequently nearly one pound in every sixteen pounds. This fraud might instantly be detected by changing the places of the sugar and weight, for then the difference would be quite material, since the sugar would then seem to want twice as much additional weight as it did really want.

FIG. 54.



Steelyard.

317. The *steelyard* differs from the balance, in having its support near one end, instead of in the middle, and also in having the weights suspended by hooks, instead of being placed in a dish.

If we suppose the beam to be 7 inches long, and the hook, C, *Fig.* 54, to be one inch from the end, then the pound weight, A, will require an additional pound at B, for every inch it is

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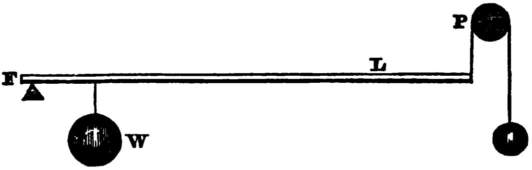
314. In the common scale-beam, where is the fulcrum? 315. In what position ought the scale-beam to hang? 316. How may a fraudulent scale-beam be made? How may the cheat be detected? 317. How does the steelyard differ from the balance?

moved from it. This, however, supposes that the bar will balance itself, before any weights are attached to it.

FIG. 55.



Lever of the Second Kind.

318. *Second Kind.*—The second kind of lever is represented by *Fig.* 55, where W is the weight, L the lever, F the fulcrum, and P a pulley, over which a string is thrown, and a weight suspended, as the power. In the common use of a lever of the first kind, the force is gained by bearing down the long arm, which is called *prying.* In the second kind, the force is gained by carrying the long arm in a contrary direction, or upward, and this is called *lifting.*

319. Levers of the second kind are not so common as the first, but are frequently used for certain purposes. The oars of a boat are examples of the second kind. The water against which the blade of the oar pushes, is the fulcrum, the boat is the weight to be moved, and the hands of the man, the power.

320. Two men carrying a load between them on a pole, is also an example of this kind of lever. Each man acts as the power in moving the weight, and at the same time each becomes the fulcrum in respect to the other.

If the weight happens to slide on the pole, the man toward whom it goes has to bear more of it in proportion as its distance from him is less than before.

321. A load at A, *Fig.* 56, is borne equally by the two men, being equally distant from each other; but at B, three quarters of its weight would be on the man at that end, because three quarters of the length of the lever would be on the side of the other man.

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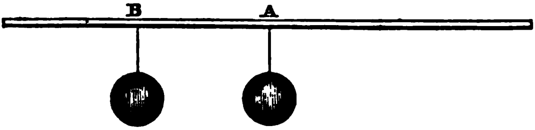
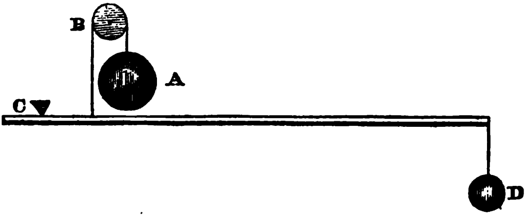
318. In the first kind of lever, where is the fulcrum, in respect to the weight and power? In the second kind, where is the fulcrum, in respect to the weight and power? What is the action of the first kind called? What is the action of the second kind called? 319. Give examples of the second kind of lever. 320. In rowing a boat, what is the fulcrum, what the weight, and what the power? 321. What other illustrations of this principle are given?

FIG. 56.



Lever—Unequal Arms.

FIG. 57



Lever of the Third Kind.

322. *Third Kind.*—In the third and last kind of lever, the weight is placed at one end, the fulcrum at the other end, and the power between them, or the hand, is between the fulcrum and the weight.

This is represented by *Fig.* 57, where C is the fulcrum, A the power, suspended over the pulley B, and D is the weight to be raised.

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FIG. 58.

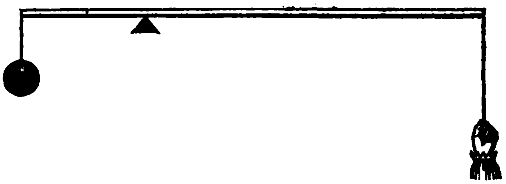


FIG. 59.

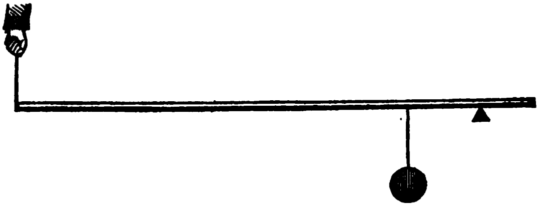
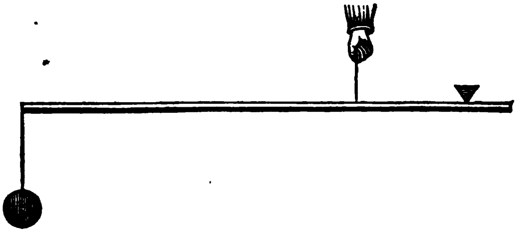


FIG. 60.



The Levers Compared.

324. In *Fig.* 58, the weight and hand both act downward. In 59, the weight and hand act in contrary directions, the hand upward and the weight downward, the weight being between them. In 60, the hand and weight also act in contrary directions, but the hand is between the fulcrum and the weight.

325. COMPOUND LEVER.—When several simple levers are connected together, and act one upon the other, the machine is

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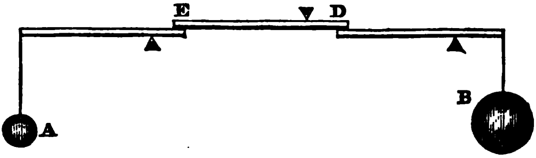
324. In what direction do the hand and weight act, in the first kind of lever? In what direction do they act in the second kind? In what direction do they act in the third kind? 325. What is a compound lever?

alled a *compound lever*. In this machine, as each lever acts as n individual, and with a force equal to the action of the next ever upon it, the force is increased or diminished, and becomes reater or less, in proportion to the number or kind of levers mployed.

We will illustrate this kind of lever by a single example, but ust refer the inquisitive student to more extended works for a ull investigation of the subject.

FIG. 61.



Compound Lever.

Fig. 61 represents a compound lever, consisting of three simple levers of the first kind.

326. In calculating the force of this lever, the rule applies which has already been given for the simple lever, namely: *The length of the long arm is to be multiplied by the moving power, and that of the short one, by the weight, or resistance.*

327. Let us suppose, then, that the three levers in the figure are of the same length, the long arms being six inches, and the short ones two inches long; required, the weight which a moving power of 1 pound at A will balance at B. In the first place, 1 pound at A, would balance 3 pounds at E, for the *lever* being 6 inches, and the power 1 pound, 6 × 1 = 6, and the short one being 2 inches, 2 × 3 = 6. The long arm of the second lever being also 6 inches, and moved with a power of 3 pounds, multiply the 3 by 6 = 18; and multiply the length of the short arm, being 2 inches, by 9 = 18. These two products being equal, the power upon the long arm of the third lever, at D, would be 9 pounds. 9 pounds × 6 = 54, and 27 × 2, is 54; so that 1 pound at A would balance 27 at B.

The increase of force is thus slow, because the proportion between the long and short arms is only as 2 to 6, or in the proportions of 1, 3, 9.

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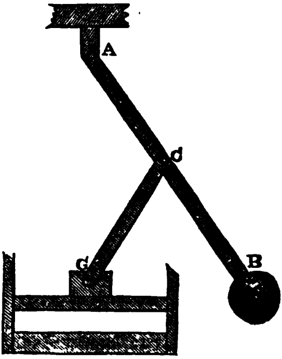
326. By what rule is the force of the compound lever calculated? 327. How many pounds weight will be raised by three levers connected, of six inches each, with the fulcrum two inches from the end, by a power of one pound?

328. Now suppose the long arms of these levers to be 18 inches, and the short ones 1 inch, and the result will be surprisingly different, for then 1 pound at A would balance 18 pounds at E, and the second lever would have a power of 18 pounds. This being multiplied by the length of the lever, 18×18=324 pounds at D. The third lever would thus be moved by a power of 324 pounds, which, multiplied by 18 inches for the weight it would raise, would give 5832 pounds.

329. The compound lever is employed in the construction of *weighing machines*, and particularly in cases where great weights are to be determined, in situations where other machines would be inconvenient, on account of their occupying too much space.

330. Knee Lever.—A compound instrument, called the *Knee Lever*, is used in various kinds of machinery, the principle of which is explained by *Fig.* 62.

FIG. 62.



Knee Lever.

This combination consists of a metal rod, A B, having a joint at A, above which there is a firm support. At C is another rod, or bar, jointed to the long lever, and terminating at G, where there is another joint, attached to a movable platform, on which the force of the two levers are exerted.

Now when B is pushed toward the vertical position, the force on the joints A and G, is constantly increased, until the two bars become perpendicular, when the pressure exerted, is augmented to nearly an indefinite degree.

331. Various engines for pressing paper, and for printing, are constructed on this principle, and it is said they are unequaled in power, except by the Hydrostatic press.

WHEEL AND AXLE.

332. The mechanical power, next to the lever in arrange-

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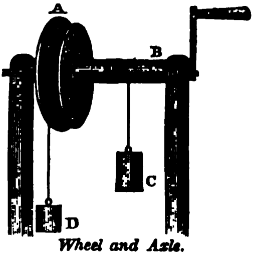
328. If the long arms of the levers be eighteen inches, and the short ones one inch, how much will a power of one pound balance? 329. In what machines is the compound lever employed? 330. Explain the principle of the Knee Lever, Fig 62. 331 What machines are on this principle?

ment, is the *wheel and axle.* It is, however, much more complex than the lever.

333. It consists of two wheels, one of which is larger than the other, but the small one passes through the larger, and hence both have a common center, on which they turn.

FIG. 63.

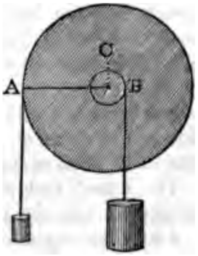


Wheel and Axle.

334. The manner in which this machine acts will be understood by *Fig.* 63. The large wheel, A, on turning the machine, will take up, or throw off, as much more rope than the small wheel or axle, B, as its circumference is greater. If we suppose the circumference of the large wheel to be four times that of the small one, then it will take up the rope four times as fast. And because A is four times as large as B, 1 pound at D will balance 4 pounds at C, on the opposite side.

335. The principle of this machine is that of the lever, as will be apparent by an examination of *Fig.* 64.

FIG. 64.



Wheel and Axle.

336. This figure represents the machine endwise, so as to show in what manner the lever operates. The two weights hanging in opposition to each other, the one on the wheel at A, and the other on the axle at B, act in the same manner as if they were connected by the horizontal lever A B, passing from one to the other, having the common center, C, as a fulcrum between them.

337. The wheel and axle, therefore, acts like a constant succession of levers, the long arm being half the diameter of the wheel, and the short one half the diameter of the axle; the common center of both being the fulcrum. The wheel and axle has, therefore, been called the *perpetual* lever.

338. The great advantage of this mechanical arrangement is, that while a single lever of the same power can raise a weight

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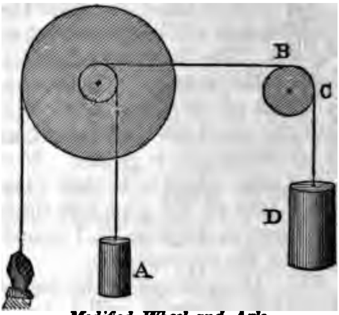
332. What is the next mechanical power to the lever? 333. Describe this machine. 334. Explain Fig. 63. 335. On what principle does this machine act? 336. In Fig. 64, which is the fulcrum, and which the two arms of the lever? 337. What is this machine called, in reference to the principle on which it acts? 338. What is the great advantage of this machine over the lever and other mechanical powers?

but a few inches at a time, and then only in a certain direction, this machine exerts a continual force, and in any direction wanted. To change the direction, it is only necessary that the rope by which the weight is to be raised, should be carried in a line perpendicular to the axis of the machine, to the place below where the weight lies, and there be let fall over a pulley.

FIG. 65.

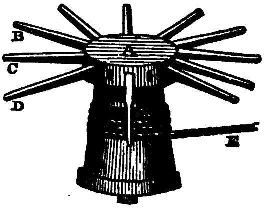


Modified Wheel and Axle.

339. Suppose the wheel and axle, *Fig.* 65, is erected in the third story of a store-house, with the axle over the scuttles, or doors through the floors, so that goods can be raised by it from the ground-floor, in the direction of the weight A. Suppose, also, that the same store stands on a wharf, where ships come up to its side, and goods are to be removed from the vessels into the upper stories. Instead of removing the goods into the store, and hoisting them in the direction of A, it is only necessary to carry the rope B, over the pulley C, which is at the end of a strong beam projecting out from the side of the store, and then the goods will be raised in the direction of B, thus saving the labor of moving them twice.

The wheel and axle, under different forms, is applied to a variety of common purposes.

FIG. 66.



Capstan.

340. The *capstan*, in universal use, on board of ships, is an axle placed upright, with a head, or drum, A, *Fig.* 66, pierced with holes for the levers B, C, D. The weight is drawn by the rope, E, passing two or three times round the axle to prevent its slipping.

341. This is a very powerful and convenient machine. When not in use, the levers are taken out

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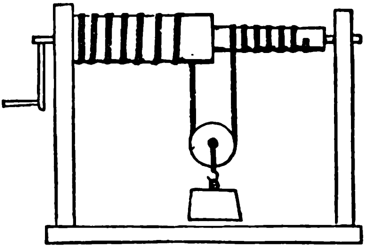
339. Describe Fig. 65, and point out the manner in which weights can be raised by letting fall a rope over the pulley. 340. What is the capstan? Where is it chiefly used? 341. What are the peculiar advantages of this form of the wheel and axle?

of their places and laid aside, and when great force is required, two or three men can push at each lever.

FIG. 67.



Windlass.

342. Windlass.—The *common windlass* for drawing water is another modification of the wheel and axle. The *winch*, or *crank*, by which it is turned, is moved around by the hand, and there is no difference in the principle, whether a whole wheel is turned, or a single spoke. The winch, therefore, answers to the wheel, while the rope is taken up, and the weight raised by the axle, as already described.

In cases where great weights are to be raised, and it is required that the machine should be as small as possible, on account of room, the simple wheel and axle, modified as represented by *Fig.* 67, is sometimes used.

343. The axle may be considered in two parts, one of which is larger than the other. The rope is attached by its two ends, to the ends of the axle, as seen in the figure. The weight to be raised is attached to a small pulley, around which the rope passes. The elevation of the weight may be thus described. Upon turning the axle, the rope is coiled around the larger part, and, at the same time, it is thrown off the smaller part. At every revolution, therefore, a portion of the rope will be drawn up, equal to the circumference of the thicker part, and at the same time a portion, equal to that of the thinner part, will be let down. On the whole, then, one revolution of the machine will shorten the rope where the weight is suspended, just as much as the difference is between the circumference of the two parts.

344. *Illustration.*—Now to understand the principle on which this machine acts, we must refer to *Fig.* 68, where it is obvious that the two parts of the rope, A and B, equally support the weight D, and that the rope, as the machine turns, passes from the small part of the axle E to the large part H, consequently,

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342. In the common windlass, what part answers to the wheel? Explain Fig. 67. 343. Why is the rope shortened, and the weight raised? 344. What is the design of Fig. 68? Does the weight rise perpendicular to the axis of motion?

of this lever will act upon the long arm of the next lever by means of the teeth on the circumference of the wheel B, and this again through the teeth on the axle of B, will transmit its force to the circumference of the wheel D, and so by the short arm of the third lever to the weight W. As the power or small weight falls, therefore, the resistance W, is raised, with the multiplied force of three levers acting on each other.

352. In respect to the force to be gained by such a machine, suppose the number of teeth on the axle of the wheel A to be six times less than the number of those on the circumference of the wheel B, then B would only turn round once, while A turns six times. And, in like manner, if the number of teeth on the circumference of D, be six times greater than those on the axle of B, then D would turn once, while B is turned six times. Thus six revolutions of A would make B revolve once, and six revolutions of B would make D revolve once. Therefore, A makes thirty-six revolutions while D makes only one.

353. The diameter of the wheel A, being three times the diameter of the axle of the wheel D, and its velocity of motion being 36 to 1, 3 times 36 will give the weight which a power of 1 pound at P would raise at W. Thus $36 \times 3 = 108$. One pound at P would therefore balance 108 pounds at W.

354. NO MACHINE CREATES FORCE.—If the student has attended closely to what has been said on mechanics, he will now be prepared to understand, that no machine, however simple or complex, can *create* the least degree of force. It is true, that one man with a machine may apply a force which a hundred could not exert with their hands, but then it would take him a hundred times as long.

355. Suppose there are 20 blocks of stone to be moved a hundred feet; perhaps twenty men, by taking each a block, would move them all in a minute. One man, with a capstan, we will suppose, may move them all at once, but this man, with his lever, would have to make one revolution for every foot he drew the whole load toward him, and therefore to make one hundred revolutions to perform the whole work. It will also take him twenty times as long to do it, as it took the twenty men. His task, indeed, would be more than twenty times harder than that performed by the twenty men, for, in addition to moving the stone, he would have the friction of the machinery

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353. What weight will one pound at P balance at W? 354. Is there any actual power gained by the use of machinery? 355. Suppose twenty men to move twenty stones to a certain distance with their hands, and one man moves them back to the same place with a capstan, which performs the most actual labor? Why?

to overcome, which commonly amounts to nearly one third of the force employed.

356. Hence there would be an actual loss of power by the use of the capstan, though it might be a convenience for the one man to do his work by its means, rather than to call in nineteen of his neighbors to assist him.

357. Any power by which a machine is moved, must be equal to the resistance to be overcome, and, in all cases where the power descends, there will be a proportion between the velocity with which it moves downward, and the velocity with which the weight moves upward.

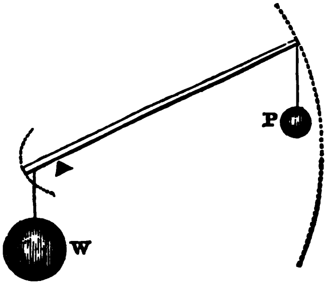
358. There will be no difference in this respect, whether the machine be simple or compound, for if its force be increased by increasing the number of levers, or wheels, the velocity of the moving power must also be increased, as that of the resistance is diminished.

359. There being, then, always a proportion between the velocity with which the moving force descends, and that with which the weight ascends, whatever this proportion may be, it is necessary that the power should have to the resistance the same ratio that the velocity of the resistance has to the velocity of the power. In other words, "*The power multiplied by the space through which it moves, in a vertical direction, must be equal to the weight multiplied by the space through which it moves in a vertical direction.*"

This law is known under the name of "the law of virtual velocities," and is considered the *golden rule* of mechanics.

360. This principle has already been explained, while treating of the lever, (312;) but that the student should want nothing to assist him in clearly comprehending so important a law, we will again illustrate it in a different manner.

FIG. 71.



Weight and Space.

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356. Why, then, is machinery a convenience? 357 In the use of the lever. what proportion is there between the force of the short arm, and the velocity of the long arm? Is it said, that the velocity of the power downward, must be in proportion to that of the weight upward? 358. Does it make any difference, in this respect, whether the machine be simple or compound? 359. What is the golden rule of mechanics? Explain Fig. 71, and show how the rule is illustrated by it.

Suppose the lever, *Fig.* 71, to be thirty inches long from the fulcrum to the point where the power, P, is suspended, and that the weight, W, is two inches from the fulcrum. If the power be 1 pound, the weight must be 15 pounds, to produce equilibrium, and the power, P, must fall thirty inches to raise the weight, W, two inches. Therefore, the power being 1 pound, and the space 30 inches, $30 \times 1 = 30$. The weight being 15 pounds, and the space 2 inches, $15 \times 2 = 30$.

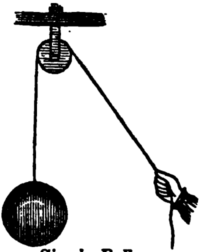
Thus, the power multiplied by the space through which it falls, and the weight multiplied by the space through which it rises, are equal.

361. However complex the machine may be, by which the force of a descending power is transmitted to the weight to be raised, the same rule will apply as it does to the action of the simple lever.

THE PULLEY.

362. *A pulley consists of a wheel which is grooved on the edge, and which is made to turn on its axis, by a cord passing over it.*

FIG. 72.



Simple Pulley.

363. *Simple Pulley.—Fig.* 72, represents a *simple pulley*, with a single fixed wheel. In other forms of the machine, the wheel moves up and down with the weight.

364. The pulley is arranged among the simple mechanical powers; but when several are connected, the machine is called a *system of pulleys*, or a *compound pulley.*

365. One of the most obvious advantages, of the pulley is, its enabling men to exert their own power in places where they can not go themselves. Thus, by means of a rope and wheel, a man can stand on the deck of a ship, and hoist a weight to the topmast.

366. By means of two fixed pulleys, a weight may be raised upward, while the power moves in a horizontal direction. The weight will also rise vertically through the same space that the rope is drawn horizontally.

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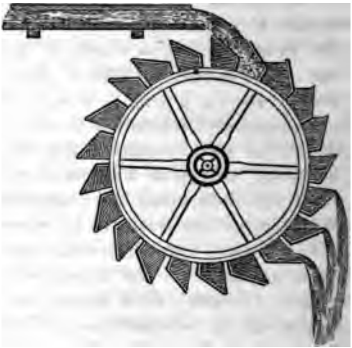
361. What is said of the application of this rule to complex machines? 362. What is a pulley? 363. What is a simple pulley? 364. What is a system of pulleys, or a compound pulley? 365. What is the most obvious advantage of the pulley? 366. How must two fixed pulleys be placed to raise a weight vertically as far as the power goes horizontally?

buckets, upon which the water acts; first, to give motion to the wheel, and then to machinery. Such wheels are of three kinds, namely: the *overshot*, *undershot*, and *breast* wheels.

504. *Overshot Wheel.*—This wheel of all others, gives the greatest power with the least quantity of water, and is, therefore, generally used when circumstances will permit, or where there is a considerable fall, with a limited quantity of water.

505. The overshot wheel, *Fig.* 114, requires a fall equal at least to its own diameter, and it is customary to give it a greater length than other wheels, that the cells or buckets may contain a large quantity of water, for it is chiefly by the weight, and not the momentum of the fluid that this wheel is turned.

FIG. 114.



Overshot Wheel.

506. In its construction, the drum, or circumference is made water-tight, and to this are fixed narrow troughs or buckets, formed of iron, or boards, running the whole length of the drum. The water is conducted by a trough nearly level, and sometimes in width equal to the length of the wheel. It falls into the buckets on the top of the wheel, and hence the name *overshot*.

507. The buckets are so constructed as to retain the water until the wheel has made about one-third of a revolution from the place of admission, when it escapes as from an inverted vessel, and the wheel ascends with empty buckets, while on the opposite side they are filled with water, and thus the revolution is perpetuated. This whole machine and its action are so plain and obvious as to require no particular reference.

508. From the experiments of Mr. Smeaton, it appears, that the fall and quantity of water, and the diameter of the wheel being the same, the overshot, will produce about double the effect of the undershot wheel.

509. *Undershot Wheel.*—This is so called because the water

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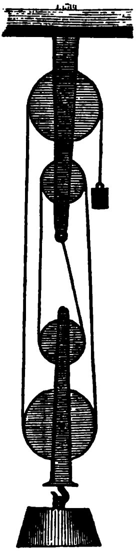
504. What is the chief advantage of the overshot wheel? 505. Is this wheel turned by the weight or momentum of the water? 506. Describe its construction. 507. What is said of the construction of the buckets? 508. Circumstances being equal, how much greater power has the overshot than the undershot wheel?

son pulling with a force of five pounds at P, will raise ten pounds at W. The mechanical force, therefore, in respect to the power, is as two to one.

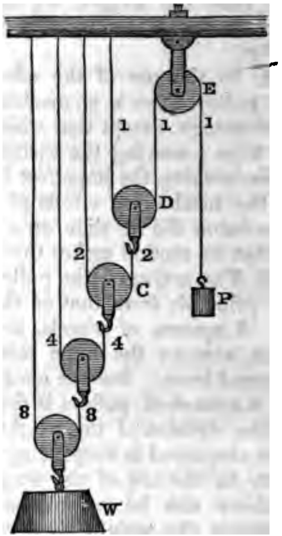
In this example, it is supposed there are only two ropes, each of which bears an equal part of the weight.

FIG. 75.



Compound Pulley.

FIG. 76.



System of Pulleys.

370. *Compound Pulley.*—If the number of ropes be increased, the weight may be increased with the same power; or the power may be diminished in proportion as the number of ropes is increased. In *Fig.* 75, the number of ropes sustaining the weight is four, and therefore, the weight may be four times as great as the power. This principle must be evident, since it is plain that each rope sustains an equal part of the weight. The weight may, therefore, be considered as divided into four parts, and each part sustained by one rope.

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370. Suppose the number of ropes be increased, and the weight increased, must the power be increased also? Suppose the weight, Fig. 75, to be thirty-two pounds, what will each rope bear?

371. In *Fig.* 76, there is a system of pulleys represented, in which the weight is sixteen times the power.

The tension of the rope, D E, is evidently equal to the power, P, because it sustains it. D, being a movable pulley, must sustain a weight equal to twice the power; but the weight which it sustains, is the tension of the second rope, D C. Hence, the tension of the second rope is twice that of the first; and, in like manner, the tension of the third rope is twice that of the second, and so on, the weight being equal to twice the tension of the last rope.

372. Suppose the weight, W, to be sixteen pounds; then the two ropes, 8 and 8, would sustain 8 pounds each, this being the whole weight divided equally between them. The next two ropes, 4 and 4, would evidently sustain but half this whole weight, because the other half is already sustained by a rope fixed at its upper end. The next two ropes sustain but half of 4, for the same reason; and the next pair, 1 and 1, for the same reason, will sustain only half of 2. Lastly, the power, P, will balance two pounds, because it sustains but half this weight, the other half being sustained by the same rope, fixed at its upper end.

It is evident that, in this system, each rope and pulley which is added will double the effect of the whole. Thus, by adding another rope and pulley beyond 8, the weight, W, might be 32 pounds, instead of 16, and still be balanced by the same power.

373. In our calculations of the effects of pulleys, we have allowed nothing for the weight of the pulleys themselves, or for the friction of the ropes. In practice, however, it will be found that nearly one-third must be allowed for friction, and that the power, therefore, to actually raise the weight must be about one-third greater than has been allowed.

374. The pulley, like other machines, obeys the laws of virtual velocities, already applied to the lever and wheel. *Thus, "in a system of pulleys, the ascent of the weight, or resistance, is as much less than the descent of the power as the weight is greater than the power."* If, as in the last example, the weight is 16 pounds, and the power 1 pound, the weight will rise only 1 foot, while the power descends 16 feet.

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371. Explain Fig. 76, and show what part of the weight each rope sustains, and why one pound at P, will balance sixteen pounds at W. 372. Explain the reason why each additional rope and pulley will double the effect of the whole, or why its weight may be double that of all the others with the same power. 373. In compound machines, how much of the power must be allowed for the friction? 374. What general law applies to the pulley?

to its place, and thus stop the discharge. The weight of this valve, a nice point in the construction of the machine, must be just sufficient to make it rise by the force of the stream, and sink again when the water ceases to flow, thus rising and falling, and in effect causing the fluid to stop for an instant, and then renew its motion.

516. Now water in motion acquires a momentum in proportion to the length of the column, and the height of the source, and when in action exerts a force equal to that of a solid body of the same length and gravity, pressing downward from the same elevation. The inelasticity of the fluid gives it the property of acquiring motion through the whole length of a tube elevated at one extremity, whenever only a small portion is allowed to escape by its own pressure. Hence, when the valve opens by dropping down, all the water in the pipe, however long it may be, instantly moves forward to supply the place of that which has thus escaped; and if the pipe is long and the fountain high, ordinary metallic conductors are burst asunder by the shock whenever the stream is interrupted. It is on these principles of the force of water, that the Hydraulic Ram is founded; for when the stream is stopped by the rising of the valve, as already explained, an outlet is provided by another valve, *u*, opening upward into an air vessel, having a discharging pipe, *x*, and consequently when the spindle valve, *t*, is closed, this valve instantly opens, and the water is thrown with great force into the air vessel, and through the discharging pipe to the place where it is wanted. The stream being thus interrupted, and the water becoming still under the lower valve, this instantly opens by falling down, thus allowing the fluid to discharge itself at *r*, when the motion again raises the valve, and it is stopped, the valve *u* being raised for its escape as before; and thus this curious machine, if well constructed, will act with no other power or help, but a little stream of water, for weeks or months.

517. This engine affords the most efficient, cheap, and convenient means of raising water, for ornamental or farming purposes, ever invented. A spring on a hill near the house, or a running brook with an elevation of a few feet, is all the power required to supply an abundance of water for any private, or even public establishment. Mr. Millington, who erected many

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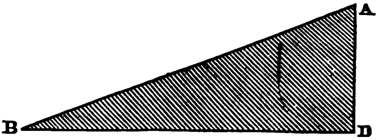
516. On what does the momentum of water in a tube depend? What is said of the motion of the water in the tube? 517. What is said of the economy and convenience of the water ram? To what heights will it throw water in proportion to the fall?

avoided, except that of a pivot at each end, and the lateral friction of a single wheel. A single rope sustains the whole, and as in other systems, the weight is as many times the power as there are ropes sustaining the lower block. This is considered the most perfect system of pulleys yet invented.

THE INCLINED PLANE.

379. *This power, the most simple of all machines, consists of a hard, smooth plane, inclined to the horizon in various degrees.* It is the fourth mechanical power, and is represented by *Fig.* 78, where from A to B is the *inclined plane;* the line from D to A, is its height, and that from B to D, its base.

FIG. 78.



Inclined Plane.

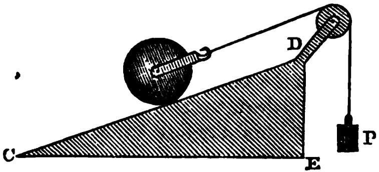
A board with one end on the ground, and the other resting on a block, becomes an inclined plane.

380. This machine being both useful and easily constructed, is in very general use, especially where heavy bodies are to be raised only to a small height. Thus a man, by means of an inclined plane, which he can readily construct with a board, or couple of bars, can raise a load into his wagon, which ten men could not lift with their hands.

381. *The power required to force a given weight up an inclined plane, is in proportion to its height, and the length of its base, or, in other words, the force must be in proportion to the rapidity of its inclination.*

382. The power, P, *Fig.* 79, pulling a weight up the inclined plane, from C to D, only raises it in an oblique direction from E to D, by acting along the whole length of the plane. If the

FIG. 79.



Inclined Plane.

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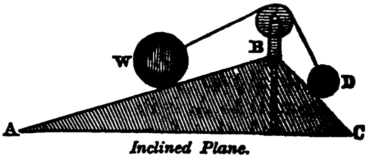
375. How may a man raise himself up by means of a rope and single fixed pulley? 376. What is a great defect in the common pulley? 377. In what manner is it said that the defect with respect to friction might be remedied? 378. Describe White's pulley, and show how the defects in other pulleys are remedied by this. 379. What is an inclined plane? 380. On what occasions is this power chiefly used? Suppose a man wants to put a barrel of cider into his wagon, how does he make an inclined plane for this purpose?

plane be twice as long as it is high, that is, if the line from C to D be double the length of that from E to D, then one pound at P will balance two pounds any where between D and C. It is evident, by a glance at this figure, that were the base lengthened, the height from E to D being the same, a less power at P would balance an equal weight any where on the inclined plane; and so, on the contrary, were the base made shorter, that is, the plane more steep, the power must be increased in proportion.

FIG. 80.

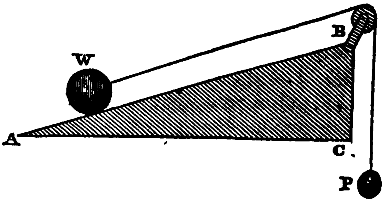


Inclined Plane.

383. Suppose two inclined planes, *Fig.* 80, of the same height, with bases of different lengths; then the weight and power will be to each other as the length of the planes. If the length from A to B is two feet, and that from B to C one foot, then two pounds at D will balance four pounds at W, and so in this proportion, whether the planes be longer or shorter.

384. The same principle, with respect to the virtual velocities of the weight and power, applies to the inclined plane, in common with the other mechanical powers.

FIG. 81.



Inclined Plane.

Suppose the inclined plane, *Fig.* 81, to be two feet from A to B, and one foot from C to B, then, as we have already seen by *Fig.* 79, a power of one pound at P, would balance a weight of two pounds at W. Now, in the fall of the power to draw up the weight, it is obvious that its vertical descent must be just twice the vertical ascent of the weight; for

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381. To roll a given weight up an inclined plane, to what must the force be proportioned? 382. Explain Fig. 79. 383. If the length of the long plane, Fig. 80, be double that of the short one, what must be the proportion between the power and the weight? 384. What is said of the application of the law of virtual velocities to the inclined plane? Explain Fig. 81, and show why the power must fall twice as far as the weight rises.

the power must fall down the distance from A to B, to draw the weight that distance; but the vertical height to which the weight W is raised, is only from C to B. Thus the power, being two pounds, must fall two feet, to raise the weight, four pounds, one foot; and thus the power and weight, multiplied by their several velocities, are equal.

When the power of an inclined plane is considered as a machine, it must therefore be estimated by the proportion which the length bears to the height; *the power being increased in proportion as the elevation of the plane is diminished.*

385. Application to Roads.—Hilly roads may be regarded as inclined planes, and loads drawn upon them in carriages, considered in reference to the powers which draw them, are subject to all the conditions which we have stated, with respect to inclined planes.

The power required to draw a load up a hill, is in proportion to the elevation of the inclined plane. On a road perfectly horizontal, if the power is sufficient to overcome the friction, and the resistance of the atmosphere, the carriage will move. But if the road rise one foot in fifteen, besides these impediments, the moving power will have to lift one fifteenth part of the load.

386. Now, where is there a section of country in which the traveler is not vexed with roads, passing straight over hills, when precisely the same distance would carry him around them on a level plane? To use a homely, but very pertinent illustration, "the bale of a pot is no longer, when it lies down, than when it stands up." Had this simple fact been noticed, and its practical bearing carried into effect by road makers, many a high hill would have been shunned for a circuit around its base, and many a poor horse, could he speak, would thank the wisdom of such a decision.

THE WEDGE.

387. *The next simple mechanical power is the wedge. This instrument may be considered as two inclined planes, placed base to base.*

It is much employed for the purpose of splitting or dividing solid bodies, such as wood and stone.

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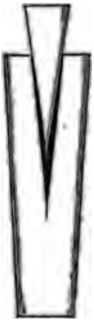
385. How do the principles of the inclined plane apply to roads? 386. What is said about the bale of a pot, as applied to road making? 387. On what principle does the wedge act? In what case is this power useful?

FIG. 82.



Wedge.

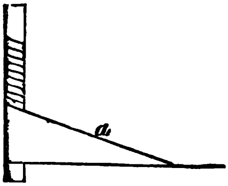
388. *Fig.* 82 represents such a wedge as is usually employed in cleaving timber. This instrument is also used in raising ships, and preparing them to launch, and for a variety of other purposes. Nails, awls, needles, and many cutting instruments, act, more or less, on the principle of this machine.

389. There is much difficulty in estimating the power of the wedge, since this depends on the force, or the number of blows given it, together with the obliquity of its sides. A wedge of great obliquity would require hard blows to drive it forward, for the same reason that a plane, much inclined, requires much force to roll a heavy body up it. But were the obliquity of the wedge, and the force of each blow given, still it would be difficult to ascertain the exact power of the wedge in ordinary cases, for, in the splitting of timber and stone, for instance, the divided parts act as levers, and thus greatly increase the power of the wedge. Thus, in a log of wood, six feet long, when split one half of its length, the other half is divided with ease, because the two parts act as levers, the lengths of which constantly increase, as the cleft extends from the wedge.

THE SCREW.

390. *The screw is the sixth and last simple mechanical power. It may be considered as a modification of the inclined plane, or as a winding wedge.*

FIG. 83.



Winding Wedge.

391. It is an inclined plane running spirally round a spindle, as will be seen by *Fig.* 83. Suppose *a* to be a piece of paper, cut into the form of an inclined plane and rolled round the piece of wood *d*; its edge would form the spiral line, called the *thread* of the screw. If the finger be placed between the two threads of a screw, and the screw be turned round once, the finger will be raised upward equal to the distance of the two

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388. What common instruments act on the principle of the wedge? 389. What difficulty is there in estimating the power of the wedge? 390. On what principle does the screw act? 391. How is it shown that the screw is a modification of the inclined plane?

thus taking the places of horses, which from the earliest times of using coal had performed this service.

662. It being therefore already known how many horses were required to raise a certain amount of coal from a given depth, the powers of these engines were very naturally compared to those of horses, and thus an engine which would perform the work of ten horses, was called an engine of *ten horse power*. To this day the same term is used, with the same meaning, though very few appear to know either the origin of the term, or the amount of power it implies.

Several engineers, after the term was thus used, made experiments, for the purpose of ascertaining the average strength of horses, with a view of fixing a standard of mechanical force which should be indicated by the term *horse power*.

This was done by means which it is not necessary here to describe.

663. Smeaton, a celebrated mechanical philosopher, estimated that the average power of the horse, working eight hours a day, was equal to the raising of 23,000 pounds at the rate of one foot per minute.

664. Messrs. Bolton and Watt caused experiments to be made with the horses used in the breweries of London, said to be the strongest in the world, and from the result they estimated that 33,000 pounds raised at the rate of one foot per minute, was the value of a horse's power, and this is the estimate now generally adopted. When, therefore, an engine is said to be so many horses' power, it is meant that it is capable of overcoming a resistance equal to so many times 33,000 pounds raised at the rate of one foot per minute. Thus an engine of ten horse power is one capable of raising a load of 330,000 pounds one foot per minute, and so at this rate, whether the power be more or less.

665. Power of Steam.—Experiment has proved that an ounce of water converted into steam will raise a weight of 2,160 pounds one foot.

666. A cubic foot of water contains 1,728 cubic inches, and the power, therefore, of a cubic foot of water, when converted

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660. What is said of accidents from steam in our country? 661. Where did the steam engine first take the place of horses? 662. What is the origin of the term horse power? 663. What was Smeaton's estimate of a horse's power? 664. What was Watt and Bolton's estimate of a horse's power? What is meant by a horse's power at the present time? How many horses would raise 33,000 pounds one foot per minute? 665. What is the power of a square inch of water converted into steam? 666. What is the power of a cubic foot of water converted into steam? How much power is lost in acting upon the engine?

such as to be limited only by the strength of the materials of which it is made.

In investigating the effects of this machine, we must, therefore, take into account both these simple mechanical powers, so that the screw now becomes really a compound engine.

396. In the inclined plane, we have already seen, that the less it is inclined, the more easy is the ascent up it. In applying the same principle to the screw, it is obvious, that the greater the distance of the threads from each other, the more rapid the inclination, and consequently, the greater must be the power to turn it, under a given weight. On the contrary, if the thread inclines but slightly, it will turn with less power, for the same reason that a man can roll a heavy weight up a plane but little inclined. Therefore, the finer the screw, or the nearer the threads to each other, the greater will be the pressure under a given power.

397. Let us suppose two screws, the one having the threads one inch apart, and the other half an inch apart; then the force which the first screw will give with the same power at the lever, will be only half that given by the second. The second screw must be turned twice as many times round as the first, to go through the same space; but what is lost in velocity is gained in power. At the lever of the first, two men would raise a given weight to a given height, by making one revolution; while at the lever of the second, one man would raise the same weight to the same height, by making two revolutions.

398. It is apparent that the length of the inclined plane, up which a body moves in one revolution, is the circumference of the screw, and its height the interval between the threads. The proportion of its power would therefore be "*as the circumference of the screw, to the distance between the threads, so is the weight to the power.*"

399. By this rule the power of the screw alone can be found; but as this machine is moved by means of the lever, we must estimate its force by the combined power of both. In this case, the circumference described by the end of the lever employed, is taken, instead of the circumference of the screw itself. The means by which the force of the screw may be found, is therefore, by multiplying the circumference which the lever describes by the power.

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396. Why does the nearness of the threads make a difference in the force of the screw? 397. Suppose one screw, with its threads one inch apart, and another half an inch apart, what will be their difference in force? 398. What is the length of the inclined plane, up which a body moves by one revolution of the screw?

400. Thus, "*the power multiplied by the circumference which it describes, is equal to the weight or resistance, multiplied by the distance between the two contiguous threads.*" Hence the efficacy of the screw may be increased, by increasing the length of the lever, or by diminishing the distance between the threads. If, then, we know the length of the lever, the distance between the threads, and the weight to be raised, we can readily calculate the power; or, the power being given, and the distance of the threads and the length of the lever known, we can estimate the weight the screw will raise.

401. Thus, suppose the length of the lever to be forty inches, the distance of the threads one inch, and the weight 8000 pounds; required, the power, at the end of the lever, to raise the weight.

The lever being 40 inches, the diameter of the circle, which the end describes, is 80 inches. The circumference is a little more than three times the diameter, but we will call it just three times. Then, 80 × 3 = 240 inches, the circumference of the circle. The distance of the threads is 1 inch, and the weight 8000 pounds. To find the power, multiply the weight by the distance of the threads, and divide by the circumference of the circle. Thus,

Circum.		In.		Weight.		Power.
240	:	1	: :	8000	:	33⅓

The power at the end of the lever must therefore be 33⅓ pounds. In practice, this power would require to be increased about one-third, on account of friction.

402. Perpetual Screw.—*The force of the screw is sometimes employed to turn a wheel, by acting on its teeth. In this case it is called the perpetual screw.*

403. *Fig.* 86 represents such a machine. It is apparent, that by turning the crank C, the wheel will revolve, for the thread of the screw passes between the cogs of the wheel. By means of an axle, through the center of this wheel, like the common wheel and axle, this becomes an exceedingly powerful machine, but like all other contrivances for obtaining great power, its effective motion is exceedingly slow. It has, however, some disadvantages, and particularly the great friction be-

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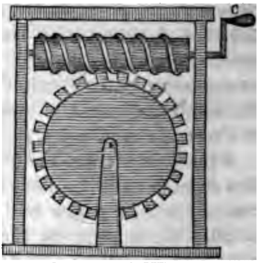
400. How is the force of the screw estimated? How may the efficacy of the screw be increased? 401. The length of the lever, the distance between the threads, and the weight being known, how can the power be found? Give an example. 402. What is the screw called when it is employed to turn a wheel? 403. Explain Fig. 86. What is the objection to this machine for raising weights?

tween the thread of the screw and the teeth of the wheel, which prevents it from being generally employed to raise weights.

FIG. 86.



Screw and Wheel.

404. All these Mechanical Powers resolved into Three.—We have now enumerated and described all the mechanical powers usually denominated simple. They are six in number, namely, the Lever, Wheel and Axle, Pulley, Wedge, Inclined Plane, and Screw.

405. In respect to the principles on which they act, they may be resolved into three simple powers, namely, the lever, the inclined plane, and the pulley; for it has been shown that the wheel and axle is only another form of the lever, and that the screw is but a modification of the inclined plane.

It is surprising, indeed, that these simple powers can be so arranged and modified, as to produce the different actions in all that vast variety of intricate machinery which men have invented and constructed.

406. Card Machine.—The variety of motions we witness in the little engine which makes cards, by being supplied with wire for the teeth, and strips of leather to stick them through, would itself seem to involve more mechanical powers than those enumerated. This engine takes the wire from a reel; bends it into the form of teeth; cuts it off; makes two holes in the leather for the tooth to pass through; sticks it through; then gives it another bend on the opposite side of the leather; graduates the spaces between the rows of teeth, and between one tooth and another; and, at the same time, carries the leather backward and forward, before the point where the teeth are introduced, with a motion so exactly corresponding with the motions of the parts which make and stick the teeth, as not to produce the difference of a hair's breadth in the distance between them.

All this is done without the aid of human hands, any further than to put the leather in its place, and turn a crank; or, in some instances, many of these machines are turned at once, by means of three or four dogs, walking on an inclined plane which revolves.

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404. How many simple mechanical powers are there, and what are they called? 405. How can they be resolved into three simple powers? 406. What is said of the card-making machine?

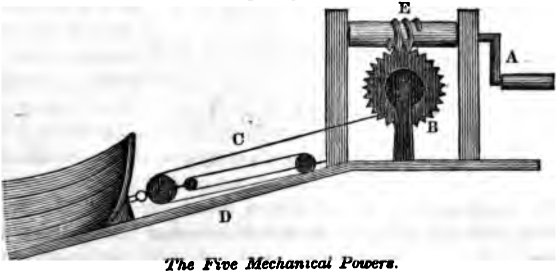
407. Such a machine displays the wonderful ingenuity and perseverance of man, and at first sight would seem to set at naught the idea that the lever and wheel are the chief simple powers concerned in its motions. But when these motions are examined singly and deliberately, we are soon convinced that the wheel variously modified, is the principal mechanical power in the whole engine.

408. USE OF MACHINERY.—It has already been stated, (354,) that notwithstanding the vast deal of time and ingenuity which men have spent on the construction of machinery, and in attempting to multiply their powers, there has, as yet, been none produced, in which the power was not obtained at the expense of velocity, or velocity at the expense of power; and, therefore, no actual force is ever generated by machinery.

When men employ the natural elements as a power to overcome resistance by means of machinery, there is a vast saving of animal labor. Thus mills, and all kinds of engines, which are kept in motion by the power of water, or wind, or steam, save animal labor equal to the power it takes to keep them in motion.

409. *Five Mechanical Powers in one Machine.*—An engineer, it is said, for the purpose of drawing a ship out of the water to be repaired, combined the mechanical powers represented by *Fig.* 87, and perhaps no machine ever constructed gives greater force with so small a power.

FIG. 87.



The Five Mechanical Powers.

It involves the lever A, wheel and axle B, the pulley C, the inclined plane D, and the screw E.

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407. What are the chief mechanical powers concerned in its motions? 408. Is there any actual force generated by machinery? What is said of employing the natural elements as a power? 409. What are the five mechanical powers employed in Fig. 87? Point out on the cut the place of each power.

To estimate the force of this engine, it is necessary to know the length of the lever, diameter of the wheel, &c.

Suppose then, the sizes of the different powers are as follows, viz. :—

Length of the lever A, ...	18 inches.
Distance of the thread E, ...	1 inch.
Diameter of the wheel B, ...	4 feet.
Diameter of the axle, ...	1 foot.
Pulleys C and D, D fixed, ...	4 strings.
Height of the plane D, one-half its length, . .	2 feet.

Suppose the man turns the lever A, with the power equal to 100 pounds, the force on the ship would thus be found, for the different laws and rules referring to each mechanical power.

	Pounds.
1. One hundred pounds on the lever A, would become a force by means of the screw on the wheel B of.	11,309.76
2. Diameter of wheel four times that of the axle, .	4
	45,239.04
3. The number of pulley strings, ...	4
	180,956.16
4. Height of the inclined plane half its lenth, . .	2
	361,912.32

The force on the ship therefore would be equal to 361,912 pounds, or about 161 tons.

CHAPTER V.

HYDROSTATICS.

410. *Hydrostatics is the science which treats of the weight, pressure, and equilibrium of water, or other fluids, when in a state of rest.*

411. *Hydraulics* is that part of the science of fluids which treats of water in motion, and the means of raising and conducting it in pipes, or otherwise, for all sorts of purposes.

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409. What must be known to estimate the power of this machine? What is the amount of force on the ship? 410. What is hydrostatics? 411. How does hydraulics differ from hydrostatics?

The subject of water at rest, will first claim investigation, since the laws which regulate its motion will be best understood by first comprehending those which regulate its pressure.

412. *A fluid is a substance whose particles are easily moved among each other, as air and water.*

413. The air is called an *elastic* fluid, because it is easily compressed into a smaller bulk, and returns again to its original state when the pressure is removed. Water is called a *non-elastic* fluid, because it admits of little diminution of bulk under pressure.

414. The non-elastic fluids are perhaps more properly called *liquids*, but both terms are employed to signify water and other bodies possessing its mechanical properties. The term *fluid*, when applied to the air, has the word *elastic* before it.

415. One of the most obvious properties of fluids, is the facility with which they yield to the impressions of other bodies, and the rapidity with which they recover their former state, when the pressure is removed. The cause of this, is the freedom with which their particles slide over, or among each other; their cohesive attraction being so slight as to be overcome by the least impression. On this want of cohesion among their particles seems to depend the peculiar mechanical properties of these bodies.

416. In solids, there is such a connection between the particles, that if one part moves, the other part must move also. But in fluids, one portion of the mass may be in motion, while the other is at rest. In solids, the pressure is always downward, or toward the center of the earth's gravity; but in fluids, the particles seem to act on each other as wedges, and hence, when confined, the pressure is sideways, and even upward, as well as downward.

417. *Elasticity of Water.*—Water has commonly been called a non-elastic substance, but it is found that under great pressure its volume is slightly diminished, and hence it is proved to be elastic. The most decisive experiments on this subject were made many years ago by Mr. Perkins.

418. These experiments were made by means of a hollow cylinder, *Fig.* 88, which was closed at the bottom, and made water-tight at the top, by a cap, screwed on. Through this

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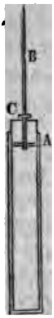
412. What is a fluid? 413 What is an elastic fluid? Why is air called an elastic fluid? 414. What substances are called liquids? 415. What is one of the most obvious properties of liquids? 416. On what do the peculiar mechanical properties of fluids depend? In what respect does the pressure of a fluid differ from that of a solid? 417. Is water an elastic, or a non-elastic fluid? 418. Describe Fig. 88, and show how water was found to be elastic.

FIG. 88.



Water Elastic.

cap, at A, passed the rod B, which was five-sixteenths of an inch in diameter. The rod was so nicely fitted to the cap, as also to be water-tight. Around the rod at C, there was placed a flexible ring, which could be easily pushed up or down, but fitted so closely as to remain on any part where it was placed.

A cannon of sufficient size to receive this cylinder, which was three inches in diameter, was furnished with a strong cap and forcing pump, and set vertically into the ground. The cannon and cylinder were next filled with water, and the cylinder, with its rod drawn out, and the ring placed down to the cap, as in the figure, was plunged into the cannon. The water in the cannon was then subjected to an immense pressure by means of the forcing pump, after which, on examination of the apparatus, it was found that the ring C, instead of being where it was placed, was eight inches up the rod. The water in the cylinder being compressed into a smaller space, by the pressure of that in the cannon, the rod was driven in, while under pressure, but was forced out again by the expansion of the water, when the pressure was removed. Thus, the ring on the rod would indicate the distance to which it had been forced in, during the greatest pressure.

419. This experiment proved that water, under the pressure of one thousand atmospheres, that is, the weight of 15,000 pounds to the square inch, was reduced in bulk about one part in 24.

So slight a degree of elasticity under such immense pressure, is not appreciable under ordinary circumstance, and therefore in practice, or in common experiments on this fluid, water is considered as non-elastic.

EQUAL PRESSURE OF WATER.

420. *The particles of water, and other fluids, when confined, press on the vessel which confines them, in all directions, both upward, downward, and sideways.*

From this property of fluids, together with their weight, very unexpected and surprising effects are produced.

The effect of this property, which we shall first examine, is,

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419. In what proportion does the bulk of water diminish under a pressure of 15,000 pounds to the square inch? In common experiments, is water considered elastic, or non-elastic? 420. When water is confined, in what direction does it press?

689. Locomotive engines are always on the high pressure principle, because such engines are more simple in structure than those of low pressure, the former not requiring the condensing apparatus which is indispensable in the latter.

CHAPTER X.

ACOUSTICS.

690. *Acoustics is that branch of natural philosophy which treats of the origin, propagation, and effects of sound.*

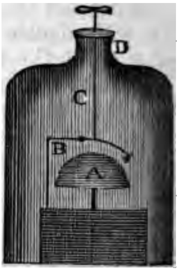
691. *Vibration of Solids.*—When a sonorous, or sounding body is struck, it is thrown into a tremulous or vibrating motion. This motion is communicated to the air which surrounds us, and by the air is conveyed to our ear drums, which also undergo a vibratory motion, and this last motion throwing the auditory nerves into action, we thereby gain the sensation of sound.

If any sounding body, of considerable size, is suspended in the air and struck, this tremulous motion is distinctly visible to the eye, and while the eye perceives its motion, the ear perceives the sound.

692. *Proof by the Air-Pump.*—That sound is conveyed to the ear by the motion which the sounding body communicates to the air, is proved by an interesting experiment with the air-pump.

693. This is done by a little piece of mechanism shown by *Fig.* 154. It consists of a block of lead weighing a pound or two, into which is inserted the standard of the bell A. A piece of wire, also fixed to the lead, is bent over the bell at B, to which is jointed the handle of a small hammer. At half an inch from the joint, the handle passes through the end of the sliding rod

FIG. 154.



About Sound.

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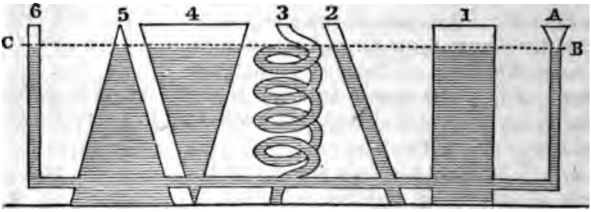
689. Why are locomotives on the high pressure principle? 690. What is acoustics? 691. When a sonorous body is struck within hearing, in what manner do we gain from it the sensation of sound? 692. How is it proved that sound is conveyed to the ear by the medium of the air? 693. Describe the mechanism, Fig. 154, by which this is proved.

and that a large quantity of water in an open vessel, press with no more force than a small quantity of the same height."

424. *Pressure equal in Vessels of all Sizes and Shapes.*—The size or shape of a vessel is of no consequence, for if a number of vessels, differing entirely from each other in figure, position, and capacity, have a communication made between them, and one be filled with water, the surface of the fluid, in all, will be at the same elevation. If, therefore, the water stands at an equal height in all, the pressure in one must be just equal to that in another, and so equal to that in all the others.

FIG. 91.



Equal Pressure of Water.

425. To make this obvious, suppose a number of vessels, of different shapes and sizes, as represented by *Fig.* 91, to have a communication between them, by means of a small tube, passing from the one to the other. If, now, one of these vessels be filled with water, or if water be poured into the tube A, all the other vessels will be filled at the same instant, up to the line B C. Therefore, the pressure of the water in A, balances that in 1, 2, 3, &c., while the pressure in each of these vessels is equal to that in the other, and so an equilibrium is produced throughout the whole series.

426. If an ounce of water be poured into the tube A, it will produce a pressure on the contents of all the other vessels, equal to the pressure of all the others on the tube: for, it will force the water in all the other vessels to rise upward to an equal height to that in the tube itself. Hence, we must conclude, that the pressure in each vessel is not only equal to that in any

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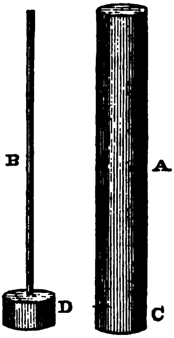
424. What difference does the shape or size of a vessel make in respect to the pressure of a fluid on its bottom? 425. Explain Fig. 91, and show how the equilibrium is produced. 426. Suppose an ounce of water be poured into the tube A, what will be its effect on the contents of the other vessels?

of the others, but also that the pressure in any one is equal to that in all the others.

427. From this, we learn that the shape or size of a vessel has no influence on the pressure of its liquid contents, but that the pressure of water is as its height, whether the quantity be great or small. We learn, also, that in no case will the weight of a quantity of liquid, however large, force another quantity, however small, above the level of its own surface.

428. Now, by other experiments, it is ascertained, *that the pressure of a liquid is in proportion to its height, and the area of its base.*

FIG. 92.



Suppose a vessel, ten feet high, and two feet in diameter, such as is represented at A, *Fig.* 92, to be filled with water; there would be a certain amount of pressure, at C, near the bottom. Let D represent another vessel, of the same diameter at the bottom, but only a foot high, and closed at the top. Now if a small tube, the fourth of an inch in diameter, be inserted into the cover of this vessel, and the tube be carried to the height of the vessel A, and then the vessel and tube be filled with water, the pressure on the bottoms and sides of both vessels at the same height will be equal, and jets of water starting from D and C will have exactly the same force, and spout to the same distance.

This might at first seem improbable, but to convince ourselves of its truth, we have only to consider, that any impression made on one portion of the confined fluid in the vessel D, is instantly communicated to the whole mass. Therefore, the water in the tube B, presses with the same force on every other portion of the water in D, as it does on that small portion over which it stands.

429. *Bursting a Cask.*—This principle is illustrated in a very striking manner, by the experiment, which has often been made, of bursting a common wine cask with a few ounces of water.

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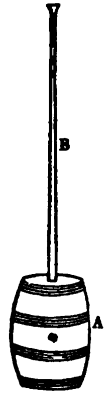
427. What conclusion is to be drawn from pouring the ounce of water into the tube A? What is the reason that a large quantity of water will not force a small quantity above its own level? Is the force of water in proportion to its height, or its quantity? 428 How is a small quantity of water shown to press equal to a large quantity, by Fig. 92? 429. Explain the reason why the pressure is as great at D, as at C.

FIG. 93.



Bursting a Cask

Suppose A, *Fig.* 93, to be such a cask, already filled with water, and suppose the tube B, fifty feet high, to be screwed, water-tight, into its head. When water is poured into the tube, so as to fill it gradually, the cask will show increasing signs of pressure, by emitting the water through the pores of the wood, and between the joints; and, finally, as the tube is filled, the cask will burst asunder.

430. The same apparatus will serve to illustrate the upward pressure of water; for, if a small stop-cock be fitted to the upper head, on turning this, when the tube is filled, a jet of water will spirt up with a force, and to a height, that will astonish all who never before saw such an experiment.

In theory, the water will spout to the same height with that which gives the pressure, but, in practice, it is found to fall short in the following proportions:—

431. If the tube be twenty feet high, and the orifice for the jet half an inch in diameter, the water will spout nearly nineteen feet. If the tube be fifty feet high, the jet will rise upward of forty feet, and if a hundred feet, it will rise above eighty feet. It is understood, in every case, that the tubes are to be kept full of water.

The height of these jets shows the astonishing effects that a small quantity of fluid produces when pressing from a perpendicular elevation.

432. Hydrostatic Paradox.—This paradox, illustrated by *Fig.* 94, consists in experimental proof of the principle already insisted on, that water presses according to its height, and not to its quantity. Fill a glass jar with water, and balance it on the scale-beam F, E, with small weights. Then pour out the water, leaving only an inch or two deep, letting the balance weights remain. Replacing the jar, which will now stand higher than before, owing to the loss of water, introduce into it, by means of the crane, H, a piece of wood a few lines smaller in all directions than the inside of the jar. The wood being

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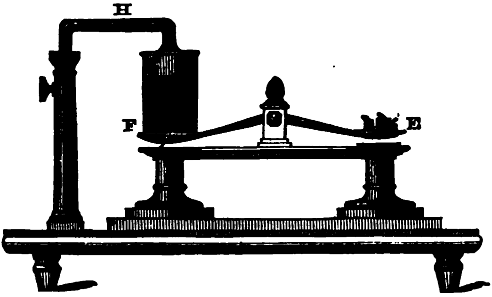
How is the same principle illustrated by Fig. 93? 430. How may Fig. 93 be made to illustrate the upward pressure of water? 431. Under the pressure of a column of water twenty feet high, what will be the height of the jet? Under a pressure of a hundred feet, how high will it rise? 432. What does the hydrostatic paradox show? Explain by the figure how the experiment is made.

FIG. 94.



Hydrostatic Paradox.

adjusted by means of the thumb-screw, so that the water is made to rise around it exactly to the brim, or as high as it stood before any was poured out, (the wood not touching the glass,) and it will be found that it will exactly balance the weights, as it did when full of water, though it now contains only a tenth as much as before.

The result will be the same if, instead of the wood, the same bulk of cork or lead be placed in the jar, the only point being, that, in each case, the water should rise to the same height.

The above experiment proves, in a very striking manner, that the pressure of water is as its height; and the reason why it makes no difference in the result whether the body placed in the jar be of wood, cork, or lead is, that the solid merely takes the place of the fluid, displacing its own bulk, and thus the weight remains just as though the water itself had remained in the jar. Thus, the pressure of a tenth part of the water, of equal height, equals the whole.

433. *Proof by Mercury.*—In addition to the above proofs, that a small, will balance a large quantity of water, we add the following, perhaps the most satisfactory of all.

Let A, B, C, *Fig.* 95, represent a glass tube, having at A, a collar cemented to the glass, into which vessels of different capacities and shapes, may be screwed. The tube is first filled with mercury up to the level of the dotted line A C, and the tube G *p*, fitted in its place. The vessel D, is then screwed into A, and water is poured in as far as *h*, the base of the column

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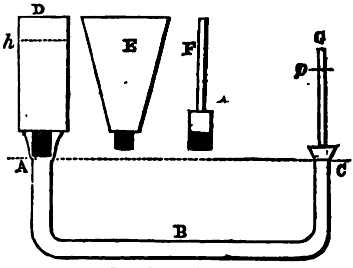
433. Explain Fig. 95, and show in what manner different quantities of water will balance the same weight of mercury.

FIG. 95.

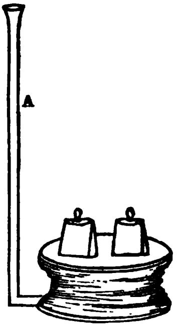


Proof by Mercury.

of water being, as seen, equal to that of the mercury. The fluid metal will rise, by the pressure of the water on A, up to *p* in the small tube. Then unscrew D, and in its place fix the conical vessel E, and pour in water as before, and the same result will follow, and so with the small tube F; in each case, the height of the water, notwithstanding the difference in quantity, will force the mercury to exactly the same elevation.

434. HYDROSTATIC BELLOWS.—An instrument called the hydrostatic bellows, also shows, in a striking manner, the great force of a small quantity of water, pressing in a perpendicular direction.

FIG. 96.



Hydrostatic Bellows.

This instrument consists of two boards, connected together with strong leather, in the manner of the common bellows. It is then furnished with a tube A, *Fig.* 96, which communicates between the two boards. A person standing on the upper board may raise himself up by pouring water into the tube. If the tube holds an ounce of water, and has an area equal to a thousandth part of the area of the top of the bellows, one ounce of water in the tube will balance a thousand ounces placed on the bellows.

435. HYDROSTATIC PRESS.—This property of water was applied by Mr. Bramah, to the construction of his *hydrostatic* press. But instead of a high tube of water, which in most cases could not be so readily obtained, he substituted a strong forcing-pump, and instead of the leather bellows, a metallic pump, barrel, and piston.

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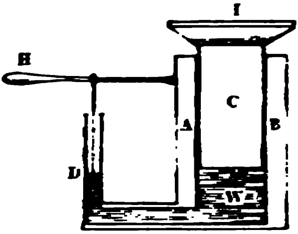
434. What is the hydrostatic bellows? What property of water is this instrument designed to show? 435. Explain Fig. 97. Where is the piston? Which is the pump-barrel in which it works?

FIG. 97.



Hydrostatic Press.

This arrangement will be understood by *Fig.* 97, where the pump-barrel, A, B, is represented as divided lengthwise, in order to show the inside. The piston, C, is fitted so accurately to the barrel, as to work up and down water-tight; both barrel and piston being made of iron. The thing to be broken or pressed, is laid on the flat surface, I, there being above this, a strong frame to meet the pressure, not shown in the figure. The small forcing-pump, of which D is the piston, and H, the lever by which it is worked, is also made of iron.

Now, suppose the space between the small piston and the large one, at W, to be filled with water, then, on forcing down the small piston, D, there will be a pressure against the large piston, C, the whole force of which will be in proportion as the aperture in which C works, is greater than that in which D works.

436. If the piston, D, is half an inch in diameter, and the piston, C, one foot in diameter, then the pressure on C will be 576 times greater than that on D. Therefore, if we suppose the pressure of the small piston to be one ton, the large piston will be forced up against any resistance, with a pressure equal to the weight of 576 tons.

437. It would be easy for a single man to give the pressure of a ton at D, by means of the lever, and, therefore, a man, with this engine, would be able to exert a force equal to the weight of near 600 tons.

438. It is evident that the force to be obtained by this principle, can only be limited by the strength of the materials of which the engine is made. Thus, if a pressure of two tons be given to a piston, the diameter of which is only a quarter of an inch, the force transmitted to the other piston, if three feet in diameter, would be upward of 40,000 tons; but such a force

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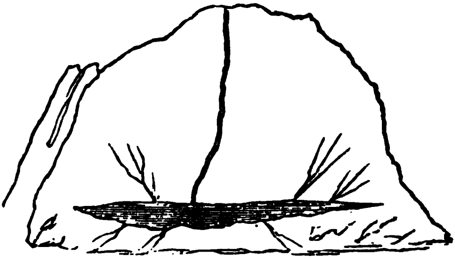
436. In the hydrostatic press, what is the proportion between the pressure given by the small piston, and the force exerted on the large one? 437. What is the estimated force which a man could give by one of these engines? 438. If the pressure of two tons be made on a piston of a quarter of an inch in diameter, what will be the force transmitted to the other piston of three feet in diameter?

is much too great for the strength of any material with which we are acquainted.

A small quantity of water, extending to a great elevation, would give the pressure above described, it being only for the sake of convenience, that the forcing-pump is employed instead of a column of water.

439. *Rupture of a Mountain.*—There is no doubt, but in the operations of nature, great effects are sometimes produced among mountains, by a small quantity of water finding its way to a reservoir in the crevices of the rocks far beneath.

FIG. 98.



Rupture of a Mountain.

Suppose, in the interior of a mountain, at A, *Fig.* 98, there should be a space of ten yards square, and an inch deep, filled with water, and closed up on all sides; and suppose that, in the course of time, a small fissure, no more than an inch in diameter, should be opened by the water, from the height of two hundred feet above, down to this little reservoir. The consequence might be, that the side of the mountain would burst asunder, for the pressure, under the circumstances supposed, would be equal to the weight of five thousand tons.

440. *Pressure on Vessels with Oblique Sides.*—It is obvious, that, in a vessel, the sides of which are every where perpendicular to each other, the pressure on the bottom will be as the height, and that the pressure on the sides will every where be equal, at an equal depth of the liquid.

But it is not so obvious, that in a vessel having oblique sides,

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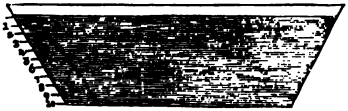
439. What is said of the pressure of water in the crevices of mountains and its effects? 440. What is the pressure on the bottom of a vessel containing a fluid equal to? Suppose the sides of the vessel slope outward, what effect does this produce on the pressure?

that is, diverging outward from the bottom, or converging from the bottom toward the top, in what manner the pressure will be sustained.

441. Now, the pressure on the bottom of any vessel, no matter what the shape may be, is equal to the height of the fluid, and the area of the bottom, (428.)

Hence the pressure on the bottom of the vessel sloping outward, *Fig.* 99, will be just equal to what it would be, were the sides perpendicular, and the same would be the case did the sides slope inward instead of outward.

FIG. 99.



Pressure on Diverging Sides.

In a vessel of this shape, the sides sustain a pressure equal to the perpendicular height of the fluid, above any given point. Thus, if the point 1 sustain a pressure of one pound, 2, being twice as far below the surface, will have a pressure equal to two pounds, and so in this proportion with respect to the other eight parts marked on the side of the vessel. On the contrary, did the sides of the vessel slope inward instead of outward, still the same consequences ensue, the vertical height in both cases making the pressure equal. For although in the latter, the elevation is not above the point of pressure, the effect is the same in each case.

PRESSURE OF WATER IN POUNDS, AT VARIOUS DEPTHS.

442. The weight of a cubic inch of water at the temperature of 62°, is the 0.036065 fraction of a pound. A column of water one foot high, being twelve times the above, would therefore be 0.4328 pounds.

443. Now a square foot is 144 square inches, and therefore the pressure, or weight, of a square foot of water will be found by multiplying the above fraction by 144, which gives 62.3232, or nearly 62 and a third pounds. Omitting the decimals, a cubic foot of water is commonly estimated at 62 pounds.

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441. On the contrary, did the sides of the vessel slope inward exactly the same amount of pressure according to the height, what would be the result? 442. What is the weight of a cubic inch of water? 443. What is the weight of a cubic foot of water?

the image of the object is shortened in proportion to the acuteness of this angle, and the object appears diminished as represented at O.

40. *The image of an object appears less, as the object is removed to a greater distance from a convex mirror.*

To explain this, let us suppose that the arrow A, *Fig.* 188, is diminished by reflection from the convex surface, so that its image appearing at D, with the eye at C, shall seem as much smaller in proportion to the object, as D is less than A. Now, keeping the eye at the same distance from the mirror, withdraw the object, so that it shall be equally distant with the eye, and the image will gradually diminish, as the arrow is removed.

The reason will be made plain by the next figure; for as the arrow is moved backward, the angle at C, *Fig.* 189, must be diminished, because the rays flowing from the extremities of the object fall a greater distance before they reach the surface of the mirror; and as the angles of the reflected rays bear a proportion to those of the incident ones, so the angle of vision will become less in proportion, as the object is withdrawn. The effect, therefore, of withdrawing the object, is first to lessen the distance between the converging rays, flowing from it, at the point where they strike the mirror, and as a consequence, to diminish the angle under which the reflected rays convey its image to the eye.

41. *Why the Image seems near the Surface.*—In the plane mirror, as already shown, the image appears exactly as far behind the mirror as the object is before it, but the convex mirror shows the image just under the surface, or, when the object is removed to a distance, a little way behind it. To understand the reason of this difference, it must be remembered, that the plane mirror makes the image seem as far behind, as the object is before it, because the rays are reflected in the same relative position at which they fall upon its surface. Thus parallel rays are reflected parallel; divergent rays equally divergent, and convergent rays equally convergent. But the convex mirror, as also above shown, (36,) reflects convergent rays less convergent, and divergent rays more divergent, and it is from this property of the convex mirror that the image appears near its surface,

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40. How is the image affected when the object is withdrawn from the surface of a convex mirror? Explain Figs. 187 and 188, and show the reason why the images are diminished when the objects are removed from the convex mirror. What is said to be the effect of withdrawing the object from a convex surface, and what the consequence on the angle of reflected rays? 41. Explain the reason why the image appears near the surface of the convex mirror.

FIG. 189.

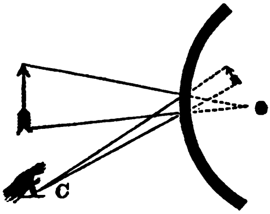
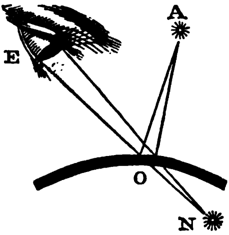


FIG. 190.



and not as far behind it as the object is before it, as in the plane mirror.

Let us suppose that A, *Fig*. 190, is a luminous point, from which a pencil of diverging rays falls upon a convex mirror. These rays, as already demonstrated, will be reflected more divergent, and consequently will meet the eye at E, in a wider state of dispersion than they fell upon the mirror at O. Now, as the image will appear at the point where the diverging rays would converge to a focus in a contrary direction, were they prolonged behind the mirror, so it can not appear as far behind the reflecting surface as the object is before it, for the more widely the rays meeting at the eye are separated, the shorter will be the distance at which they will come to a point. The image will, therefore, appear at N, instead of appearing at an equal distance behind the mirror that the object A is before it.

CONCAVE MIRROR.

42. *The reflection of the concave mirror takes place from its inside, or concave surface, while that of the convex mirror is from the outside, or convex surface.* Thus the section of a metallic sphere, polished on both sides, is both a *concave* and *convex* mirror, as one or the other side in employed for reflection.

The effects and phenomena of this mirror will therefore be, in many respects, directly the contrary from those already detailed in reference to the convex mirror.

From the *plane* mirror, the relation of the incident rays is not changed by reflection; from the *convex* mirror they are dis-

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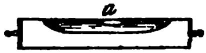
42. What is the shape of the concave mirror, and in what respect does it differ rom the convex mirror? How may convex and concave mirrors be united in the ame instrument? What is the difference of effect between the concave, convex, nd plane mirrors, on the reflected rays?

liquid, and will therefore be level. But if one of these points be more distant from the floats than the other, the line joining the intersections will point upward if viewed from the lower sight, and downward if viewed from the higher one.

The accuracy of the results of this instrument, will be greatly increased by lengthening the tube A.

FIG. 101.



Spirit Level.

447. *Spirit Level.*—The common *spirit level* consists of a glass tube, *Fig.* 101, filled with spirit of wine, excepting a small space in which there is left a bubble of air. This bubble, when the instrument is laid on a level surface, will be exactly in the middle of the tube, and therefore, to adjust a level, it is only necessary to bring the bubble to this position.

The glass tube is inclosed in a brass case, which is cut out on the upper side, so that the bubble may be seen, as represented in the figure.

448. This instrument is employed by builders to level their work, and is highly convenient for that purpose, since it is only necessary to lay it on a beam to try its level.

SPECIFIC GRAVITY.

449. *If a tumbler be filled with water to the brim, and an egg, or any other heavy solid, be dropped into it, a quantity of the fluid, exactly equal to the size of the egg, or other solid, will be displaced, and will flow over the side of the vessel.* Bodies which sink in water, therefore, displace a quantity of the fluid equal to their own bulks.

450. Now, it is found by experiment, that when any solid substance sinks in water, it loses, while in the fluid, a portion of its weight, just equal to that of the bulk of water which it displaces. This is readily made evident by experiment.

451. Take a piece of ivory, or any other substance that will sink in water, and weigh it accurately in the usual manner; then suspend it by a thread, or hair, in the empty cup A, *Fig.* 102, and balance it, as shown in the figure. Now pour water into the cup, and it will be found that the suspended body will lose a part of its weight, so that a certain number of grains

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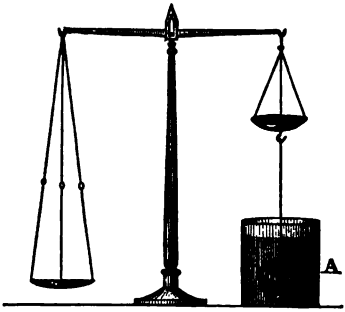
447. Describe the common spirit level, and the method of using it. 448. What is the use of the level? 449. How much water will an egg displace? 450. How much less will a cubic inch of any substance weigh in water than in air? 451. How is it proved by Fig. 102, that a body weighs less in water than in air?

FIG. 102.



Weighing in Water.

must be taken from the opposite scale, in order to make the scales balance as before the water was poured in. The number of grains taken from the opposite scale, show the weight of a quantity of water equal to the bulk of the body so suspended.

452. It is on the principle, that bodies weigh less in the water than they do when weighed out of it, or in the air, that water becomes the means of ascertaining their specific gravities, for it is by comparing the weight of a body *in* the water, with what it weighs *out* of it, that its specific gravity is determined.

Thus, suppose a cubic inch of gold weighs 19 ounces, and on being weighed in water, weighs only 18 ounces, or loses a nineteenth part of its weight, it will prove that gold, bulk for bulk, is nineteen times heavier than water, and thus 19 would be the specific gravity of gold. And so if a cube of copper weigh 9 ounces in the air, and only 8 ounces in the water, then copper, bulk for bulk, is 9 times as heavy as water, and therefore has a specific gravity of 9.

453. If the body weighs less, bulk for bulk, than water, it is obvious that it will not sink in it, and therefore weights must be added to the lighter body, to ascertain how much less it weighs than water.

The specific gravity of a body, then, is merely its weight compared with the same bulk of water; and water is thus made the standard by which the weights of all other bodies are compared.

454. *How to take the Specific Gravity.*—To take the specific gravity of a solid which sinks in water, first weigh the body in the usual manner, and note down the number of grains it weighs; then, with a hair, or fine thread, suspend it from the bottom of the scale-dish, in a vessel of water, as represented by *Fig.* 102. As it weighs less in water, weights must be added to the side of the scale where the body is suspended, until they

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452. On what principle are specific gravities found? 453. What is the specific gravity of a body? 454. How are the specific gravities of solid bodies taken?

exactly balance each other. Next, note down the number of grains so added, and they will show the difference between the weight of the body in air and in water.

455. It is obvious that the greater the specific gravity of the body, the less, comparatively, will be this difference, because each body displaces only its own bulk of water, and some bodies of the same bulk will weigh many times more than others.

456. For example, suppose that a piece of platina, weighing 22 ounces, will displace an ounce of water, while a piece of silver, weighing 22 ounces, will displace two ounces of water. The platina, therefore, when suspended as above described, will require one ounce to make the scales balance, while the same weight of silver will require two ounces for the same purpose. The platina, therefore, bulk for bulk, will weigh twice as much as the silver, and will have twice as much specific gravity.

Having noted down the difference between the weight of the body in air and in water, as above explained, the specific gravity is found by dividing the weight in air by the loss in water. The greater the loss, therefore, the less will be the specific gravity, the bulk being the same.

457. Thus, in the above example, 22 ounces of platina was supposed to lose one ounce in water, while 22 ounces of silver lost two ounces in water. Now, 22 divided by 1, the loss of the platina, is 22; and 22 divided by 2, the loss in the silver, is 11. So that the specific gravity of platina is 22, while that of silver is 11. The specific gravities of these metals are, however, a little less than here estimated.

458. TABLE OF SPECIFIC GRAVITIES.

Antimony,	7	Platinum,	20
Zinc,	7	" hammered,	22
Cast Iron,	7	Mercury,	14
Tin,	8	Agate,	2½
Cobalt,	8	Sulphur,	2
Steel,	8	Glass, crown,	2½
Copper,	9	" flint,	3½
Bismuth,	10	Rock, crystal,	2½
Silver,	10	Marble,	2½
Lead,	11	Diamonds,	3½
Gold,	19	Ruby, (oriental,)	4½

This table being intended for common use, the fractions are omitted, and the nearest round numbers only given.

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455 Why does a heavy body weigh comparatively less in the water than a light one? 456 Having taken the difference between the weight of a body in air and in water, by what rule is its specific gravity found? 457. Give the example stated, and show how the difference between the specific gravities of platina and silver is found.

HYDROMETER.

459. *The hydrometer is an instrument by which the specific gravities of fluids are ascertained by the depth to which the instrument sinks below their surfaces.*

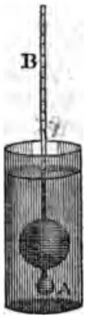
460. Suppose a cubic inch of lead loses, when weighed in water, 253 grains, and, when weighed in alcohol, only 209 grains, then, according to the principle already recited, a cubic inch of water actually weighs 253, and a cubic inch of alcohol 209 grains, for when a body is weighed in a fluid, it loses just the weight of the fluid it displaces.

461. Water, as we have already seen, (453,) is the standard by which the weights of other bodies are compared, and by ascertaining what a given bulk of any substance weighs in water, and then what it weighs in any other fluid, the comparative weight of water and this fluid will be known. For if, as in the above example, a certain bulk of water weighs 253 grains, and the same bulk of alcohol only 209 grains, then alcohol has a specific gravity nearly one-fourth less than water.

462. It is on this principle that the hydrometer is constructed. It is composed of a hollow ball of glass, or metal, with a graduated scale rising from its upper part, and a weight on its under part, which serves to balance it in the fluid.

Such an instrument is represented by *Fig.* 103, of which B is the graduated scale, and A, the weight, the hollow ball being between them.

FIG. 103.



Hydrometer.

463. To prepare this instrument for use, weights in grains, or half-grains, are put into the little cup, A, until the scale is carried down so that a certain mark on it coincides exactly with the surface of the water. This mark, then, becomes the standard of comparison between water and any other liquid in which the hydrometer is placed.

464. If plunged into a fluid lighter than water, it will sink below the mark, and, consequently, the fluid will rise higher on

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459. What is the hydrometer? 460. Suppose a cubic inch of any substance weighs 253 grains less in water than in air, what is the actual weight of a cubic inch of water? 461. On what principle is the hydrometer founded? 462. How is this instrument formed? 463. How is the hydrometer prepared for use? 464. How is it known by this instrument whether the fluid is lighter or heavier than water?

the scale. If the fluid is heavier than water, the scale will rise above the surface in proportion, and thus it is ascertained in a moment whether any fluid has a greater or less specific gravity than water.

To know precisely how much the fluid varies from the standard, the scale is marked off into degrees, which indicate grains by weight, so that it is ascertained very exactly how much the specific gravity of one fluid differs from that of another.

465. Water being the standard by which the weights of other substances are compared, it is placed as the unit, or point of comparison, and is, therefore, 1, 10, 100, or 1000, the ciphers being added whenever there are fractional parts expressing the specific gravity of the body. It is always understood, therefore, that the specific gravity of water is 1; and when it is said a body has a specific gravity of 2, it is only meant that such a body is, bulk for bulk, twice as heavy as water.

466. If the substance is lighter than water, it has a specific gravity of 0, with a fractional part. Thus, alcohol has a specific gravity of 0.809, that is, 809, water being 1000.

467. By means of this instrument, it can be told with great accuracy how much water has been added to spirits, for the greater the quantity of water, the higher will the scale rise above the surface.

The adulteration of milk with water, can also be readily detected with it, for as new milk has a specific gravity of 1032, water being 1000, a very small quantity of water mixed with it would be indicated by the instrument.

THE SIPHON.

468. Take a tube bent like the letter U, and, having filled it with water, place a finger on each end, and in this state plunge one of the ends into a vessel of water, so that the end in the water shall be a little the highest; then remove the fingers and the liquid will flow out, and continue to do so until the vessel is exhausted.

469. A tube acting in this manner is called a *siphon*, and is

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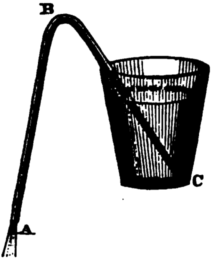
465. What is the standard by which the weights of other bodies are compared? What is the specific gravity of water? When it is said that the specific gravity of a body is 2, or 4, what meaning is intended to be conveyed? 466. If alcohol has a specific gravity of 809; what, in reference to this, is the specific gravity of water? 467. In what cases will the hydrometer detect fraud? 468. In what manner is a siphon made? 469. Explain the reason why the water ascends through one leg of the siphon, and descends through the other?

FIG. 104.

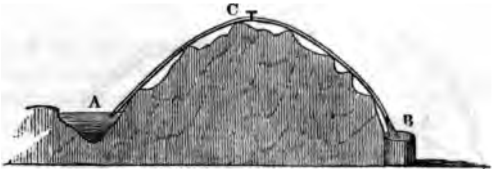


Siphon.

represented by *Fig.* 104. The reason why the water flows from the end of the tube, A, and, consequently, ascends through the other part, is, that there is a greater weight of the fluid from B to A, than from C to B, because the perpendicular height from B to A, is the greatest. The weight of the water from B to A, falling downward by its gravity, tends to form a vacuum, or void space, in that leg of the tube; but the pressure of the atmosphere on the water in the vessel, constantly forces the fluid up the other leg of the tube, to fill the void space, and thus the stream is continued as long as any water remains in the vessel.

470. *Application of the Siphon.*—The siphon is employed in draining mines, when there is a sufficient fall in the vicinity: it may also be used to convey water over a hill, provided the place where it is wanted is a foot or two lower than the fountain.

FIG. 105.



Application of the Siphon.

For this purpose, let A be a spring, *Fig.* 105, situated behind a hill, and it is desired to bring the water to B for family use. To do this, a lead tube, with a stop-cock at C, is carried over the hill, having also a stop-cock at each end. This done, and the two ends being closed, fill the two legs of the tube by pouring in water at C; then C being closed, let one person open the stop-cock at B, and a moment after, open that at A, and the water will instantly begin to flow from the spring to the reservoir, and if C is kept closed, will continue to run so long as the fountain furnishes water.

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470. Explain by Fig. 105, how the siphon conveys water over a hill.

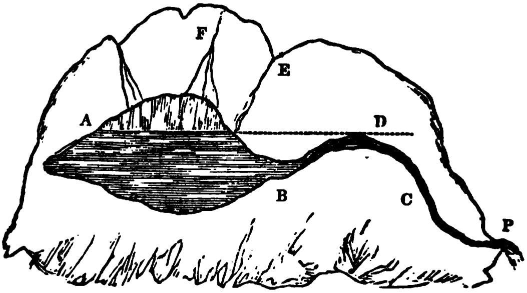
The principle of the siphon has been explained under *Fig.* 104.

INTERMITTING SPRINGS.

471. The action of the siphon depends upon the same principle as the action of the pump, namely, the pressure of the atmosphere, and, therefore, its explanation properly belongs to Pneumatics. It is introduced here merely for the purpose of illustrating the phenomena of intermitting springs, a subject which belongs to Hydrostatics.

Some springs, situated on the sides of mountains, flow, for a while, with great violence, and then cease entirely. After a time they begin to flow again, and then suddenly stop, as before. These are called *intermitting springs.* Among ignorant and superstitious people, these strange appearances have been attributed to witchcraft, or the influence of some supernatural power. But an acquaintance with the laws of nature will dissipate such ill-founded opinions, by showing that they owe their peculiarities to nothing more than natural siphons, existing in the mountains from whence the water flows.

FIG. 106.



Intermitting Spring.

472. *Fig.* 106 is the section of a mountain and spring, showing how the principle of the siphon operates to produce the effect described. Suppose there is a crevice, or hollow, in the rock from A to B, and a narrow fissure leading from it, in the form of the siphon, B C. The water from the rills F E,

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471. What is an intermitting spring? 472. How is the phenomenon of the intermitting spring explained?

filling the hollow, up to the line A D, it will then discharge itself through the siphon, and continue to run until the water is exhausted down to the leg of the siphon B, when it will cease. Then the water from the rills continuing to run until the hollow is again filled up to the same line, the siphon again begins to act, and again discharges the contents of the reservoir as before, and thus the spring P, at one moment flows with great violence and the next moment ceases entirely.

473. The hollow, above the line A D, is supposed not to be filled with the water at all, since the siphon begins to act whenever the fluid rises up to the bend D.

During the dry seasons of the year, it is obvious, that such a spring would cease to flow entirely, and would begin again only when the water from the mountain filled the cavity through the rills.

CHAPTER VI.

HYDRAULICS.

474. *It has been stated*, (410,) *that Hydrostatics is that branch of Natural Philosophy, which treats of the weight, pressure, and equilibrium of fluids, and that Hydraulics has for its object, the investigation of the laws which regulate fluids in motion.*

If the pupil has learned the principles on which the pressure and equilibrium of fluids depend, as explained under the former article, he will now be prepared to understand the laws which govern fluids when in motion.

475. The pressure of water downward, is in the same proportion to its height, as is the pressure of solids in the same direction.

476. Suppose a vessel of three inches in diameter has a billet of wood set up in it, so as to touch only the bottom, and suppose the piece of wood to be three feet long, and to weigh nine pounds; then the pressure on the bottom of the vessel will be

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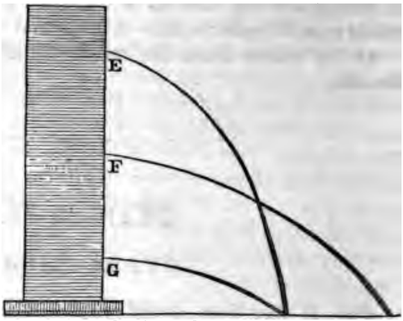
472. Explain Fig. 106, and show the reason why such a spring will flow and cease to flow, alternately. 474. How does the science of Hydrostatics differ from that of Hydraulics? 475. Does the downward pressure of water differ from the downward pressure of solids, in proportion? 476. How is the downward pressure of water illustrated?

nine pounds. If another billet of wood be set on this, of the same dimensions, it will press on its top with the weight of nine pounds, and the pressure at the bottom will be eighteen pounds, and if a like billet be set on this, the pressure at the bottom will be twenty-seven pounds, and so on, in this ratio, to any height the column is carried.

Now the pressure of fluids is in the same proportion; and when confined in pipes, may be considered as one short column set on another, each of which increases the pressure of the lowest, in proportion to their number and height.

FIG. 107



Velocity and Gravity.

477. If a vessel, *Fig.* 107, be filled with water, and three apertures be made in its side at E F G, the fluid will be thrown out in jets, falling to the earth in the curved lines shown. The reason why these curves differ in shape, is, that the fluid is acted on by two forces, namely, the pressure of the water above the jet, which produces its velocity forward, and the action of gravity, which impels it downward. It therefore obeys the same laws that solids do when projected forward, and falls down in curved lines, the shapes of which depend on their relative velocities, (246.)

478. The quantity of water discharged, being in proportion to the pressure, when the orifices are the same, that discharged from each orifice will differ in quantity, according to the height of the water above it.

479. It is found, however, that the velocity with which a vessel discharges its contents, does not depend entirely on the pressure, but in part on the kind of orifice through which the liquid flows. It might be expected, for instance, that a tin ves-

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477. Why do the lines described by the jets from the vessel, Fig. 107, differ in shape? What two forces act upon the fluid as it is discharged, and how do these forces produce a curved line? 478. In what proportion do the orifices discharge the fluid? 479. Does the velocity with which a fluid is discharged, depend entirely on the pressure?

sel of a given capacity, with an orifice of, say an inch in diameter, would part with its contents sooner than another of the same capacity and orifice, whose side was an inch or two thick, since the friction through the tin might be considered much less than that presented by the other orifice.

480. But it has been found, by experiment, that the tin vessel does not part with its contents so soon as another vessel, of the same height and size of orifice, from which the water flowed through a short pipe. And, on varying the length of these pipes, it is found that the most rapid discharge, other circumstances being equal, is through a pipe, whose length is twice the diameter of its orifice. Such an aperture discharged 82 quarts, in the same time that another vessel of tin, without the pipe, discharged 62 quarts.

481. This surprising difference is accounted for, by supposing that the cross currents, made by the rushing of the water from different directions toward the orifice, mutually interfere with each other, by which the whole is broken, and thrown into confusion by the sharp edge of the tin, and hence the water issues in the form of spray, or of a screw, from such an orifice. A short pipe seems to correct this contention among opposing currents, and to smooth the passage of the whole, and hence we may observe, that from such a pipe, the stream is round and well defined. ☞

482. *Proportion between the Pressure and the Velocity of Discharge.*—If a small orifice be made in the side of a vessel filled with any liquid, the liquid will flow out with a force and velocity equal to the pressure which the liquid before exerted on that portion of the side of the vessel before the orifice was made.

Now, as the pressure of fluids is as their heights, it follows, that if several such orifices are made, the lowest will discharge the greatest, while the highest will discharge the least quantity of the fluid.

The velocity of discharge, in the several orifices of such a vessel, will show a remarkable coincidence between the ratio of increase in the quantity of liquid, and the increased velocity of a falling body.

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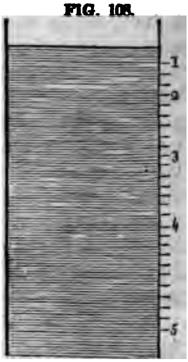
480. What circumstance, besides pressure, facilitates the discharge of water from an orifice? In a tube discharging water with the greatest velocity, what is the proportion between its diameter and its length? What is the proportion between the quantity of fluid discharged through an orifice of tin and through a short pipe? 481. How is this difference explained? 482. What are the proportions between the velocities of discharge and the heights of the orifices, as above explained?

483. Thus, if the tall vessel, *Fig.* 108, of equal dimensions throughout, be filled with the water, and a small orifice be made at one inch from the top, or below the surface, as at 1; and another at 2, 4 inches below this; another at 9 inches; a fourth at 16 inches; and a fifth at 25 inches; then the velocities of discharge, from these several orifices, will be in proportion of 1, 2, 3, 4, 5.

FIG. 108.



Velocity of Discharge.

484. To make this more obvious, we will place the expressions of the several velocities in the upper line of the following table, the lower numbers expressing the depths of the several orifices.

Velocity, ...	1	2	3	4	5	6	7	8	9	10
Depth, ...	1	4	9	16	25	36	49	64	81	100

Thus it appears, as in falling bodies, that to produce a twofold velocity a fourfold height is necessary. To obtain a threefold velocity of discharge, a ninefold height is required, and for a fourfold velocity, sixteen times the height, and so in this proportion, as shown by the table, (111.)

In order to establish the fact, that the velocity with which a liquid spouts from an orifice, is equal to the velocity which a body would acquire in falling unobstructed from the surface of the liquid to the depth of the orifice, it is only necessary to prove the truth of the principle in any one particular case.

Now it is manifestly true, if the orifice be presented downward, and the column of fluid over it be of small height, then this indefinitely small column will drop out of the orifice by the mere effect of its own weight, and, therefore, with the same velocity as any other falling body; but as fluids transmit pressure in all directions, the same effect will be produced, whatever may be the direction of the orifice.

FRICTION BETWEEN SOLIDS AND FLUIDS.

485. The rapidity with which water flows through pipes of the same diameter, is found to depend much on the nature

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483. If in Fig. 108. orifices are made at the distance of 1, 4, 9. 16, and 25 inches from the top, then in what ratio of velocity will the water be discharged? 484. How is it proved that the velocity of the spouting liquid is equal to that of a falling body? 485. Suppose a lead and a glass tube, of the same diameter; which will deliver the greatest quantity of liquid in the same time? Why will a glass tube deliver most?

of their internal surfaces. Thus a lead pipe, with a smooth aperture, under the same circumstances, will convey much more water than one of wood, where the surface is rough, or beset with points. In pipes, even where the surface is as smooth as glass, there is still considerable friction, for in all cases, the water is found to pass more rapidly in the middle of the stream than it does on the outside, where it rubs against the sides of the tube.

486. The sudden turns, or angles of a pipe, are also found to be a considerable obstacle to the rapid conveyance of the water, for such angles throw the fluid into eddies or currents by which its velocity is arrested.

In practice, therefore, sudden turns are generally avoided, and where it is necessary that the pipe should change its direction, it is done by means of as large a circle as convenient.

487. *Water in Pipes.*—Where it is proposed to convey a certain quantity of water to a considerable distance in pipes, there will be a great disappointment in respect to the quantity actually delivered, unless the engineer takes into account the friction, and the turnings of the pipes, and makes large allowances for these circumstances. If the quantity to be actually delivered ought to fill a two-inch pipe, one of three inches will not be too great an allowance, if the water is to be conveyed to any considerable distance.

In practice, it will be found that a pipe of two inches in diameter, one hundred feet long, will discharge about five times as much water as one of one inch in diameter of the same length, and under the same pressure.

488. This difference is accounted for, by supposing that both tubes retard the motion of the fluid, by friction, at equal distances from their inner surfaces, and consequently that the effect of this cause is much greater in proportion, in a small tube, than in a large one.

489. *Flowing of Rivers.*—The effect of friction in retarding the motion of fluids is perpetually illustrated in the flowing of rivers and brooks. On the side of a river, the water, especially where it is shallow, is nearly still, while in the middle of a stream it may run at the rate of five or six miles an hour. For the same reason, the water at the bottoms of rivers is much less

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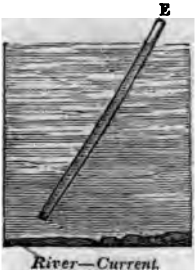
486. What is said of the sudden turnings of a tube, in retarding the motion of the fluid? 487. How much more water will a two-inch tube of a hundred feet long discharge, than a one-inch tube of the same length? 488. How is this difference accounted for? 489. How do rivers show the effect of friction in retarding the motion of their waters?

rapid than at the surface. This is often proved by the oblique position of floating substances, which in still water would assume a vertical direction.

Thus, suppose the stick of wood E, *Fig.* 109, to be loaded at one end with lead, of the same diameter as the wood, so as to make it stand upright in still water. In the current of a river, where the lower end nearly reaches the bottom, it will incline as in the figure, because the water is more rapid toward the surface than at the bottom, and hence the tendency of the upper end to move faster than the lower one, gives it an inclination forward.

FIG. 109.



River—Current.

MACHINES FOR RAISING WATER.

490. The common pump, though a hydraulic machine, depends on the pressure of the atmosphere for its effect, and therefore its explanation comes properly under the article Pneumatics, where the consequences of atmospheric pressure will be illustrated.

Such machines only as raise water without the assistance of the atmosphere, come properly under the present article.

491. ARCHIMEDES' SCREW.—Among these, one of the most curious, as well as ancient machines, is the *screw of Archimedes*, and which was invented by that celebrated philosopher, two hundred years before the Christian era, and then employed for raising water, and draining land in Egypt.

492. It consists of a tube, made of lead, or strong leather, coiled round a cylinder of wood or iron, as represented by *Fig.* 110. It has a support at each end, turning on gudgeons, the upper end being sometimes furnished with cog-wheels to give a more easy and rapid motion. Both ends are open, the lower one being placed so far under the water as not to allow the orifice to come above the surface in turning; the other discharges the water in an uninterrupted stream.

493. The angle at which these machines work depends on the manner of winding the tube on the cylinder; that is,

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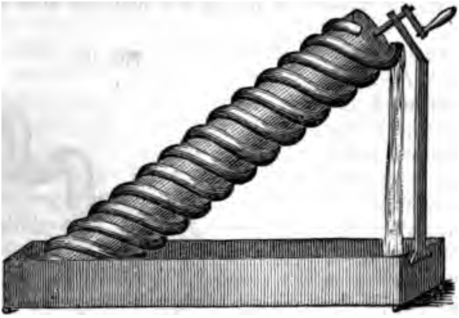
Explain Fig. 109. 490. What is said of the common pump? 491. Who is said to have been the inventor of Archimedes' screw? When was this screw invented? 492. Explain this machine, as represented in Fig. 110. and show how the water is elevated by turning it. 493. What must be the inclination of this machine?

FIG. 110.



Archimedes' Water Screw.

whether the folds touch each other, or are at a distance apart, for it is obvious that if the tube passes only a few times around the support, this must be in nearly a horizontal position to act; but if the folds nearly touch, as in the figure, it may be placed at an angle of about 50° with the horizon. It will be apparent that the direction of each fold must be toward the horizon, as the screw turns, otherwise the water would not run. This is shown by the figure. This machine, as above stated, is a very ancient invention, but has been re-invented in modern times, and employed in most parts of Europe.

It has been constructed in various ways besides that here represented. One was, to cut a spiral groove in a large log of wood, and cover this with metal, leather, or boards, so as to make it hold the water. The screw being thus sunk into the wood, instead of being on the outside, as commonly represented.

494. When it was necessary to raise the water to a great height, a series, one obliquely above the other, were employed, platforms being constructed, with vessels to contain the water, the lower end of the second screw taking that which was elevated by the first; the third receiving that carried up by the second, and so on. At present we believe this engine is no where used except as a curiosity, there being better means of raising water.

495. This principle is readily illustrated by winding a piece of lead tube round a walking-stick, and then turning the whole with one end in a dish of water, as shown in the figure.

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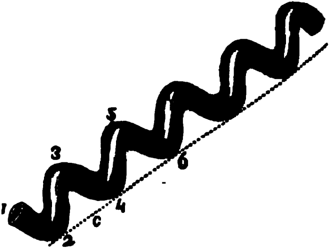
494. How was water raised to great heights by this machine? 495. How may the principle of Archimedes' screw be readily illustrated?

Theory of Archimedes' Screw.—By the following cut and explanation, the manner in which this machine acts will be understood.

FIG. 111.



496. Suppose the extremity 1, *Fig.* 111, to be presented upward, as in the figure, the screw itself being inclined as represented. Then, from its peculiar form and position, it is evident, that commencing at 1, the screw will descend until we arrive at a certain point, 2; in proceeding from 2 to 3, it will ascend. Thus, 2 is a point so situated that the parts of the screw on both sides of it ascend, and therefore if any body, as a ball, were placed in the tube at 2, it could not move in either direction without ascending. Again, the point 3 is so situated, that the tube on each side of it descends; and as we proceed we find another point, 4, which, like 2, is so placed, that the tube on both sides of it ascends, and, therefore, a body placed at 4, could not move without ascending. In like manner, there is a series of other points along the tube, from which it either descends or ascends, as is obvious by inspection.

Now let us suppose a ball, less in size than the bore of the tube, so as to move freely in it, to be dropped in at 1. As the tube descends from 1 to 2, the ball of course will descend down to 2, where it will remain at rest.

Next, suppose the ball to be fastened to the tube at 2, and suppose the screw to be turned nearly half round, so that the end 1 shall be turned downward, and the point 2 brought to the highest point of the curve 1, 2, 3.

497. The last movement of the spiral, it is evident, would so change the positions of the ascending and descending parts, as to continue the motion upward, but it must be remembered that the water differs from the ball used for illustration, in having a constant pressure downward, and consequently upward, and that the ascent of the water depends on this property of the action of fluids.

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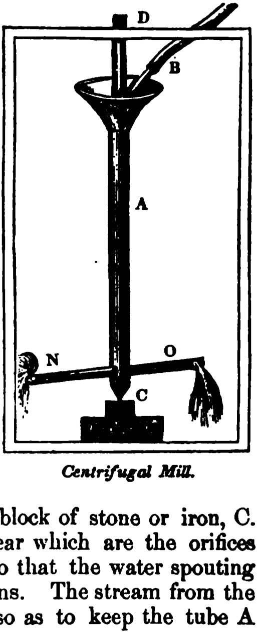
496. Explain the manner in which a ball would ascend, Fig. 111, by turning the screw. 497. On what property of fluids does the ascent of the water depend?

498. Barker's Mill.—For the different modes of applying water as a power for driving mills, and other useful purposes, we must refer the reader to works on practical mechanics. There is, however, one method of turning machinery by water, invented by Dr. Barker, which is strictly a philosophical, and, at the same time, a most curious invention, and therefore is properly introduced here.

This machine is called *Barker's centrifugal mill*, and such parts of it as are necessary to understand the principle on which it acts are represented by *Fig.* 112.

FIG. 112.



Centrifugal Mill.

The upright cylinder A, is a tube which has a funnel-shaped mouth for the admission of the stream of water from the pipe B. This tube is six or eight inches in diameter, and may be from ten to twenty feet long. The arms, N and O, are also tubes communicating freely with the upright one, from the opposite sides of which they proceed. The shaft D is firmly fastened to the inside of the tube, openings at the same time being left for the water to pass to the arms O and N. The lower part of the tube is solid, and turns on a point resting on a block of stone or iron, C. The arms are closed at their ends, near which are the orifices on the sides opposite to each other, so that the water spouting from them will fly in opposite directions. The stream from the pipe B, is regulated by a stop-cock, so as to keep the tube A constantly full without overflowing.

499. To set this engine in motion, nothing is required but the force of the water, which being let in by the pipe, descends, and spouting from the opposite orifices, the motion immediately begins, and if the main tube is of sufficient length, and kept full of water, it will in a few minutes acquire a whirling velocity which will astonish any one who has not before seen this curious machine.

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498. Describe Barker's centrifugal mill, Fig. 112. 499. How is this mill set in motion?

500. With respect to the theory of its motion, Euler, Gregory, Brande and others, have written; and it was formerly supposed to depend in part on the resistance of the atmosphere, but on trial it is said to revolve most rapidly in a vacuum. It is therefore difficult to explain very clearly on what its motion does depend. Dr. Gregory says, "In this machine the water does not act by its weight, or momentum, but by its centrifugal force, and the reaction that is produced by the flowing of the water on the point immediately behind the orifice of discharge." Dr. Brande says, "The resistance, or reaction generated by the water issuing from the holes, is such as to throw the vertical pipe with its arms and axis into rapid rotatory motion."

A model of the running part of this mill may be made by any tinner, for a few shillings, and may be kept in constant motion, as a curiosity, by the waste water from the water ram described a few pages hence. The shaft may be from two to four feet in length, and an inch or two in diameter, the arms being one-half or one-third this size. The orifices in the arms must be small, otherwise too much water will be required, the quantity discharged being much greater than might be supposed.

After a few revolutions, the machine will receive an additional impulse by the centrifugal force generated in the arms, and in consequence of this, a much more violent and rapid discharge of the water takes place, than would occur by the pressure of that in the upright tube alone. The centrifugal force, and the force of the discharge thus acting at the same time, and each increasing the force of the other, this machine revolves with great velocity and proportionate power. The friction which it has to overcome, when compared with that of other machines, is very slight, being chiefly at the point C, where the weight of the upright tube and its contents is sustained.

By fixing a cog-wheel to the shaft at D, motion may be given to any kind of machinery required.

Where the quantity of water is small, but its height considerable, this machine may be employed to great advantage, it being under such circumstances one of the most powerful engines ever invented. †

CHAIN PUMP.

501. The principle of this machine is ancient, but instead of flat boards, as in *Fig.* 113, pots, or deep buckets, were em-

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500. What is the theory of Barker's mill? 501. What is said of the antiquity and use of the chain-pump? Describe the construction and action of this machine.

Let a ray pass toward a mirror in the line A C, *Fig.* 176, it will be reflected off in the direction C D, making the angles 1 and 2 exactly equal.

The ray A C, is called the *incident* ray, and the ray C D, the *reflected* ray; and it is found, in all cases, that whatever angle the ray of incidence makes with the reflecting surface, or with a perpendicular line drawn from the reflecting surface, exactly the same angle is made by the reflected ray.

25. From these facts, arises the general law in optics, that the *angle of reflection is equal to the angle of incidence.*

The ray A C, *Fig.* 177, is the ray of incidence, and that from C to D, is the ray of reflection. The angles which A C, make with the perpendicular line, and with the plane of the mirror, are exactly equal to those made by C D, with the same perpendicular, and the same plane surface.

MIRRORS.

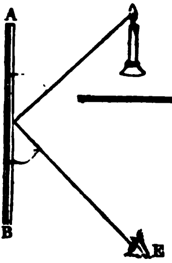
26. *Mirrors are of three kinds, namely, plane, convex, and concave. They are made of polished metal, or of glass covered on the back with an amalgam of tin and quicksilver.*

Plane Mirror.—The common *looking-glass* is a plane mirror, and consists of a plate of ground glass so highly polished as to permit the rays of light to pass through it with little interruption. On the back of this plate is placed the reflecting surface, which consists of a mixture of tin and mercury. The glass plate, therefore, only answers the purpose of sustaining the metallic surface in its place,—of admitting the rays of light to and from it, and of preventing its surface from tarnishing, by excluding the air. Could the metallic surface, however, be retained in its place, and not exposed to the air, without the glass plate, these mirrors would be much more perfect than they are, since, in practice, glass can not be made so perfect as to transmit all the rays of light which fall on its surface.

27. When applied to the plane mirror, the angles of incidence and of reflection are equal, as already stated; and it therefore follows, that when the rays of light fall upon it obliquely in one direction, they are thrown off under the same angle in the opposite direction.

What is an incident ray of light? What is a reflected ray of light? 25. What general law in optics results from observations on the incident and reflected rays? 26. How many kinds of mirrors are there? What kind of mirror is the common looking-glass? Of what use is the glass plate in the construction of this mirror? 27. Explain Fig 178, and show how the image of an object can be seen in a plane mirror when the real object is invisible.

FIG. 178.



Equal Angles.

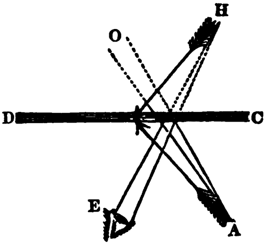
This is the reason why the images of objects can be seen when the objects themselves are not visible.

Suppose the mirror, A B, *Fig.* 178, to be placed on the side of a room, and a lamp to be set in another room, but so situated as that its light would shine upon the glass. The lamp itself could not be seen by the eye placed at E, because the partition D is between them; but its image would be visible at E, because the angle of the incident ray, coming from the light, and that of the reflected ray which reaches the eye, are equal.

28. *An image from a plane mirror appears to be just as far behind the mirror, as the object is before it, so that when a person approaches this mirror, his image seems to come forward to meet him; and when he withdraws from it, his image appears to be moving backward at the same rate.*

If, for instance, one end of a rod, two feet long, be made to touch the surface of such a mirror, this end of the rod, and its image, will seem nearly to touch each other, there being only the thickness of the glass between them; while the other end of the rod, and the other end of its image, will appear to be equally distant from the point of contact.

FIG. 179.



Plane Mirror.

29. The reason of this is explained on the principle that the angle of incidence and that of reflection are equal.

Suppose the arrow A to be the object reflected by the mirror D C, *Fig.* 179; the incident rays A, flowing from the end of the arrow, being thrown back by reflection, will meet the eye in the same state of divergence that they would do, if they proceed to the same distance behind the mirror, that the eye is before it, as at O. Therefore, by the same law, the reflected rays, where they meet the eye at E, appear to diverge from a

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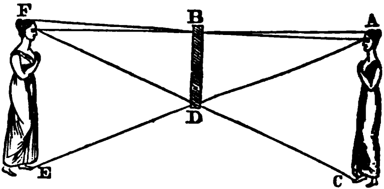
28. The image of an object appears just as far behind a plane mirror, as the object is before it. 29. Explain Fig. 179, and show why this is the case.

point H, just as far behind the mirror as A is before it, and consequently the end of the arrow most remote from the glass will appear to be at H, or the point where the approaching rays would meet, were they continued onward behind the glass. The rays flowing from every other part of the arrow follow the same law; and thus every part of the image seems to be at the same distance behind the mirror that the object really is before it.

30. *In a plane mirror, a person may see his whole image, when the mirror is only half as long as himself, let him stand at any distance from it whatever.*

This is also explained by the law, that the angles of incidence and reflection are equal. If the mirror be elevated so that the ray of light from the eye falls perpendicularly upon the mirror, this ray will be thrown back by reflection in the same direction, so that the incident and reflected ray by which the image of the eyes and face are formed, will be nearly parallel, while the ray flowing from his feet will fall on the mirror obliquely, and will be reflected as obliquely in the contrary direction, and so of all the other rays by which the image of the different parts of the person is formed.

FIG. 180.



Mirror half the Length of the Object.

This will be understood by *Fig.* 180, where the ray of light A B, proceeding from the eye, falling perpendicularly on the plane mirror B D, will be reflected back in the same line; but the ray C D coming from the feet, which falls obliquely on the mirror, will be reflected back under the same angle in the line D A; and since we see objects in the direction of the reflected rays, and the image appears at the same distance behind the mirror that the object is before it, (28,) we must continue the line A D to the feet, E, and for the same reason, the rays A B, from the eye, must be prolonged to F, as far behind the mirror as the line E extends, where the whole image will be represented.

Now, the line D E, behind the mirror, is just equal to D A

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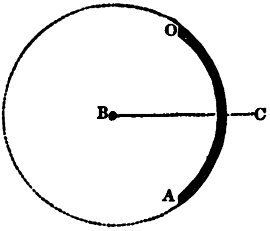
30. What must be the comparative length of a plane mirror in which a person may see his whole image? Explain, by the lines in Fig. 180, why it is that a lady may see herself in a mirror one half her length.

before it; and the distance of A C is just twice that of B D; herefore, the whole person is seen in a mirror of half its length, the image being as far behind the reflector as the object is before it.

31. A shorter mirror would not show the whole person, because the rays coming from the feet would fall so obliquely upon it as to be reflected above his head, and thus could not be seen; but another placed there might see the whole image, though the owner could not.

32. CONVEX MIRROR.—*A convex mirror is a part of a sphere, or globe, reflecting from the outside.*

FIG. 181.



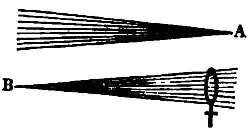
Convex Mirror.

Suppose *Fig.* 181 to be a sphere, then the part from A to O, would be a section of the sphere. Any part of a hollow ball of glass, with an amalgam of tin and quicksilver spread on the inside, or any part of a metallic globe polished on the outside, would form a convex mirror.

The *axis* of a convex mirror, is a line, as C B, passing through its center.

33. *Divergent and Convergent Rays.*—Rays of light are said to *diverge*, when they proceed from the same point, and constantly recede from each other, as from the point A, *Fig.* 182. Rays of light are said to *converge*, when they approach in such a direction as finally to meet at a point, as at B, *Fig.* 182.

FIG. 182.



Rays of Light.

The image formed by a plane mirror, as we have already seen, is of the same size as the object, but the image reflected from the convex mirror is always smaller than the object.

The law which governs the passage of light with respect to the angles of incidence and reflection, to and from the convex mirror, is the same as already stated, for the plane mirror.

34. From the surface of a plane mirror, parallel rays are re-

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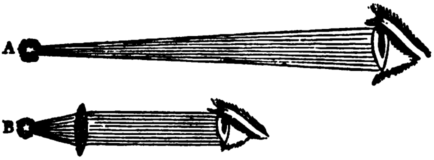
31. Why can not a person see his whole figure in a mirror less than half his length? 32. What is a convex mirror? What is the axis of a convex mirror? 33. What are diverging rays? What are converging rays? What law governs the passage of light from and to the convex mirror?

FIG. 217.



Single Microscope.

seen distinctly, and B, the distance at which the same object is seen through the lens, and suppose the distance of A from the eye, be twice that of B. Then, because the object is at half the distance that it was before, it will appear twice as large; and had it been seen one-third, one-fourth, or one-tenth its former distance, it would have been magnified three, four, or ten times, and consequently its surface would be increased 9, 16, or 100 times.

The most powerful single microscopes are made of minute globules of glass, which are formed by melting the ends of a few threads of spun glass in a flame of alcohol. Small globules of water placed in an orifice through a piece of tin, or other thin substance, will also make very powerful microscopes. In these minute lenses, the focal distance is only a tenth or twelfth part of an inch from the lens, and therefore the eye, as well as the object to be magnified, must be brought very near the instrument.

81. Compound Microscope.—This consists of two convex lenses, by one of which the image is formed within the tube of the instrument, and by the other this image is magnified as seen by the eye; so that by this instrument the object itself is not seen, as with the single microscope, but we see only its magnified image.

The small lens placed near the object, and by which its image is formed within the tube, is called the *object glass*, while the larger one, through which the image is seen, is called the *eyeglass*.

This arrangement is represented at *Fig.* 218. The object A is placed a little beyond the focus of the object glass B, by which an inverted and enlarged image of it is formed within the in-

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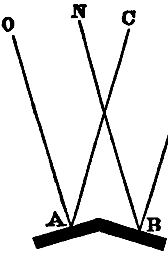
81. How many lenses form the compound microscope? Which is the object, and which the eyeglass? Is the object seen with this instrument, or only its image? Explain Fig. 218, and show where the image is formed in this tube.

the same manner as a plane mirror, and the whole, in the manner of a number of minute mirrors inclined from each other.

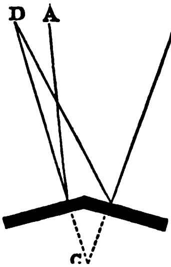
Suppose A and B, *Fig.* 184, to be the points on a convex mirror, from which the two parallel rays, C and D, are reflected. Now, from the surface of a plane mirror, the reflected rays would be parallel, whenever the incident ones are so, because each will fall upon the surface under the same angles. But it is obvious, in the present case, that these rays fall upon the surfaces, A and B, under different angles, as respects the surfaces, C approaching in a more oblique direction than D; consequently C is reflected more obliquely than D, and the two reflected rays, instead of being parallel as before, diverge in the direction of N and O.

FIG. 184.



Plane Surface.

FIG. 185.



Convergent.

Again, the two converging rays A and B, *Fig.* 185, without the interposition of the reflecting surfaces, would meet at C, but because the angles of reflection are equal to those of incidence, and because the surfaces of reflection are inclined from each other, these rays are reflected less convergent, and instead of meeting at the same distance before the mirror that C is behind it, are sent off in the direction of D, at which point they meet.

36. "*Thus parallel rays falling on a convex mirror, are rendered divergent by reflection; converging rays are made less convergent, or parallel, and diverging rays more divergent.*

The effect of the convex mirror, therefore, is to disperse the

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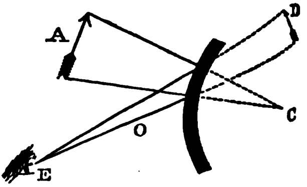
36. What effect does the convex mirror have upon parallel rays by reflection? What is its effect on converging rays? What is its effect on diverging rays? Do the rays of light proceed only from the extremities of objects, as represented in figures, or from all their parts? Do all the rays of light proceeding from an object enter the eye, or only a few of them?

rays of light in all directions; and it is proper here to remind the pupil, that although the rays of light are represented on paper by single lines, there are, in fact, probably millions of rays, proceeding from every point of all visible bodies. Only a comparatively small number of these rays, it is true, can enter the eye, for it is only by those which proceed in straight lines from the different parts of the object, and enter the pupil, that the sense of vision is excited.

37. When, therefore, it is said, that the convex mirror disperses the rays of light which fall upon it from any object, and when the direction of these reflected rays are shown only by single lines, it must be remembered, that each line represents pencils of rays, and that the light not only flows from the parts of the object thus designated, but from all the other parts. Were this not the case, the object would be visible only at certain points.

38. CURVED IMAGES.—*The images of objects reflected from the convex mirror, appear curved, because their different parts are not equally distant from its surface.*

FIG. 186.



Curved Image.

If the object A be placed obliquely before the convex mirror, *Fig.* 186, then the converging rays from its two extremities falling obliquely on its surface, would, were they prolonged through the mirror, meet at the point C, behind it. But instead of being thus continued, they are thrown back by the mirror in less convergent lines, which meet the eye at E, it being, as we have seen, one of the properties of this mirror, to reflect converging rays less convergent than before.

The image being always seen in the direction from which the rays approach the eye, it appears behind the mirror at D. If the eye be kept in the same position, and the object, A, be moved further from the mirror, its image will appear smaller, in a proportion inversely to the distance to which it is removed. Consequently, by the same law, the two ends of a straight object will appear smaller than its middle, because they are further

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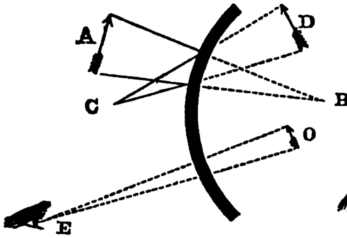
37. What would be the consequence, if the rays of light proceeded only from the parts of an object shown in diagrams? 38. Why do the images of objects reflected from convex mirrors appear curved? Why do the features of the face appear out of proportion by this mirror?

from the reflecting surface of the mirror. Thus, the images of straight objects, held before a convex mirror, appear curved, and for the same reason, the features of the face appear out of proportion, the nose being too large, and the cheeks too small, or narrow.

39. *Why Objects appear Large or Small.*—Objects appear to be large or small, in proportion to the angle which the rays of light, proceeding from their extreme parts, form, when they meet at the eye. For it is plain that the half of any object will appear under a less angle than the whole, and the quarter under a less angle still. Therefore the smaller an object is, the smaller will be the angle under which it will appear at a given distance. *Hence the image of an object, when reflected from the convex mirror, appears smaller than the object itself.* This will be understood by Fig. 187.

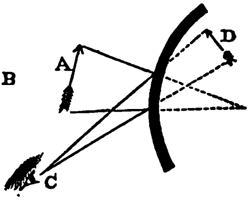
Suppose the rays flowing from the extremities of the object A, to be reflected back to C, under the same degrees of convergence at which they strike the mirror; then, as in the plane mirror, the image D would appear of the same size as the object A; for if the rays from A were prolonged behind the mirror, they would meet at B, but forming the same angle, by reflection, that they would do, if thus prolonged, the object seen from B, and its image from C, would appear of the same dimensions.

FIG. 187.



Object Diminished.

FIG. 188.



Convex Mirror.

But instead of this, the rays from the arrow A, being rendered less convergent by reflection, are continued onward, and meet the eye under a more acute angle than at C, the angle under which they actually meet, being represented at E, consequently

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39. Why does an image reflected from a convex surface appear smaller than the object? Why does the half of an object appear to the eye smaller than the whole?

the image of the object is shortened in proportion to the acuteness of this angle, and the object appears diminished as represented at O.

40. *The image of an object appears less, as the object is removed to a greater distance from a convex mirror.*

To explain this, let us suppose that the arrow A, *Fig.* 188, is diminished by reflection from the convex surface, so that its image appearing at D, with the eye at C, shall seem as much smaller in proportion to the object, as D is less than A. Now, keeping the eye at the same distance from the mirror, withdraw the object, so that it shall be equally distant with the eye, and the image will gradually diminish, as the arrow is removed.

The reason will be made plain by the next figure; for as the arrow is moved backward, the angle at C, *Fig.* 189, must be diminished, because the rays flowing from the extremities of the object fall a greater distance before they reach the surface of the mirror; and as the angles of the reflected rays bear a proportion to those of the incident ones, so the angle of vision will become less in proportion, as the object is withdrawn. The effect, therefore, of withdrawing the object, is first to lessen the distance between the converging rays, flowing from it, at the point where they strike the mirror, and as a consequence, to diminish the angle under which the reflected rays convey its image to the eye.

41. *Why the Image seems near the Surface.*—In the plane mirror, as already shown, the image appears exactly as far behind the mirror as the object is before it, but the convex mirror shows the image just under the surface, or, when the object is removed to a distance, a little way behind it. To understand the reason of this difference, it must be remembered, that the plane mirror makes the image seem as far behind, as the object is before it, because the rays are reflected in the same relative position at which they fall upon its surface. Thus parallel rays are reflected parallel; divergent rays equally divergent, and convergent rays equally convergent. But the convex mirror, as also above shown, (36,) reflects convergent rays less convergent, and divergent rays more divergent, and it is from this property of the convex mirror that the image appears near its surface,

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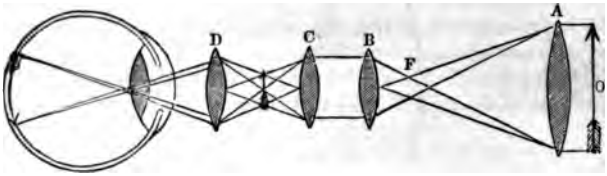
40. How is the image affected when the object is withdrawn from the surface of a convex mirror? Explain Figs. 187 and 188, and show the reason why the images are diminished when the objects are removed from the convex mirror. What is said to be the effect of withdrawing the object from a convex surface, and what the consequence on the angle of reflected rays? 41. Explain the reason why the image appears near the surface of the convex mirror.

FIG. 222.



Refracting Telescope.

that diverging rays are rendered parallel by refraction through a convex lens. The rays, therefore, pass parallel to the next lens C, by which they are made to converge, and cross each other, and thus the image is inverted, and made to assume the original position of the object O. Lastly, this image, being in the focus of the eyeglass D, is seen in the natural position.

The apparent magnitude of the object is not changed by these two additional glasses, but depends, as in *Fig.* 220, on the magnifying power of the eye and object lenses; these two glasses being added merely for the purpose of making the image appear erect.

86. REFLECTING TELESCOPE.—The common reflecting telescope consists of a large tube, containing two concave reflecting mirrors, of different sizes, and two eyeglasses. The object is first reflected from the large mirror to the small one, and from the small one, through the two eyeglasses, where it is then seen.

In comparing the advantages of the two instruments, it need only be stated, that the refracting telescope with a focal length of a thousand feet, if it could be used, would not magnify distinctly more than a thousand times, while a reflecting telescope, only eight or nine feet long, will magnify with distinctness twelve hundred times.

The principle and construction of the reflecting telescope will be understood by *Fig.* 223. Suppose the object O to be at such a distance, that the rays of light from it pass in parallel lines, P P, to the great reflector, R R. This reflector being concave, the rays are converged by reflection, and cross each other at A, by which the image is inverted. The rays then pass to the small mirror, B, which being also concave, they are thrown back in nearly parallel lines, and having passed the

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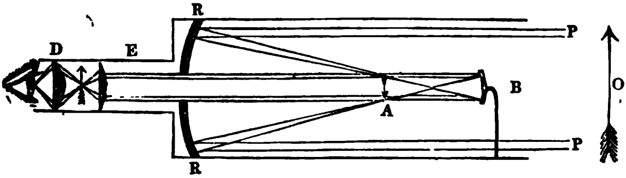
86. How many lenses and mirrors form the reflecting telescope? What are the advantages of the reflecting over the refracting telescope? Explain Fig. 223, and show the course of the rays from the object to the eye. Why is the small mirror in *this instrument* made to move by means of a screw?

Telescope,

FIG. 223.



Reflecting Telescope.

aperture in the center of the great mirror, fall on the plano-convex lens E. By this lens they are refracted to a focus, and cross each other between E and D, and thus the image is again inverted, and brought to its original position, or in the position of the object. The rays then passing the second eyeglass, form the image of the object on the retina.

The large mirror in this instrument is fixed, but the small one moves backward and forward, by means of a screw, so as to adjust the image to the eyes of different persons. Both mirrors are made of a composition, consisting of several metals melted together.

87. One great advantage which the reflecting telescope possesses over the refracting, appears to be, that it admits of an eyeglass of shorter focal distance, and, consequently, of greater magnifying power. The convex object glass of the refracting instrument, does not form a perfect image of the object, since some of the rays are dispersed, and others colored by refraction. This difficulty does not occur in the reflected image from the metallic mirror of the reflecting telescope, and consequently it may be distinctly seen, when more highly magnified.

The instrument just described is called "*Gregory's telescope*," because some parts of the arrangement were invented by Dr. Gregory.

88. *Herschel's Telescope.*—In Dr. Herschel's grand telescope, the largest then constructed, the reflector was 48 inches in diameter, and had a focal distance of 40 feet. This reflector was three and a half inches thick, and weighed 2000 pounds. Now, since the focus of a concave mirror is at the distance of one-half the semi-diameter of the sphere, of which it is a sec-

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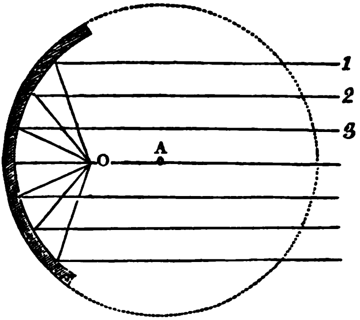
87. What is the advantage of the reflecting telescope in respect to the eyeglass? 88. What was the focal distance and diameter of the mirror in Dr. Herschel's great telescope? Where is the largest Herschel's telescope now in existence? What is the diameter and focal distance of the reflector of this telescope?

FIG. 192.

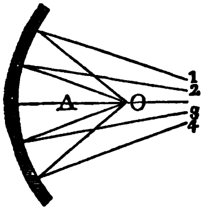


Focus of a Concave Mirror.

45. *Principal Focus.*—In concave mirrors, of all dimensions, the reflected rays follow the same law; that is, parallel rays meet and cross each other at the distance of one-fourth the diameter of the sphere of which they are sections. This point is called the *principal* focus of the reflector.

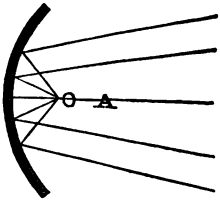
But if the incident rays are divergent, the focus will be removed to a greater distance from the surface of the mirror, than when they are parallel, in proportion to their divergence.

FIG. 193.



Divergent Rays.

FIG. 194



Convergent Rays.

This might be inferred from the general laws of incidence and reflection, but will be made obvious by *Fig.* 193, where the diverging rays 1, 2, 3, 4, form a focus at the point O, whereas, had they been parallel, their focus would have been at A. That is, the actual focus is at the center of the sphere, instead of being half way between the center and circumference, as is the case when the incident rays are parallel. The real focus, therefore, is beyond, or without, the principal focus of the mirror.

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45. What is the principal focus of a concave mirror? If the incident rays are divergent, where will be the focus? If the incident rays are convergent, where will be the focus?

position by means of spirit levels. The crucibles were 10 hours in the furnace before the metal was sufficiently fluid to cast. The speculum weighed 3 tons—lost one-eighth of an inch in thickness by grinding.

Grinding.—The grinding was conducted under water, the moving power being a steam-engine of 3 horse power. The grinder is of cast iron with grooves in its face to retain the emery, and the two faces having a mutual motion, both became perfect, whatever might have been their inequalities. The polishing was done by means of a thin layer of pitch spread on the grinder, on which rouge was smeared in the form of paste with water. This process took six hours.

Construction of the Tube.—The tube is 56 feet long, made of boards and hooped with iron. On the inside at intervals of 8 feet, are iron rings to support the boards. Its diameter is 7 feet, the whole being easily moved in any direction by means of pulleys and levers, a universal joint at the lower end being designed for this purpose.

Wall of Support.—At a distance of 12 feet, on each side of the instrument is a brick wall, 72 feet long, 48 high on the outside, and 56 on the inside, ranging exactly on the meridianal line. These walls have rods of iron and wood passing from one to the other, for the support of the telescope, as it is turned in different directions.

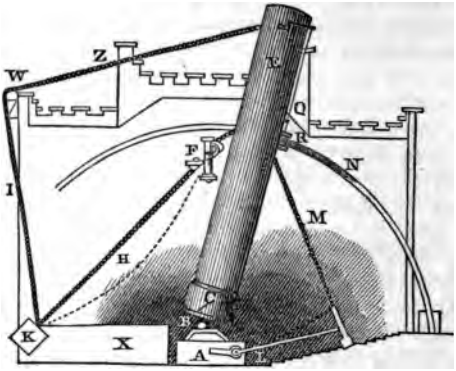
The weight of the speculum and tube, including that of the bed on which it is sustained, is about 15 tons.

This being a reflecting telescope, the observer stands in a gallery at the upper end, and looks into the side of the great tube, where the observations are made by means of a reflecting surface of 4,071 square inches, while Herschel's great reflector had a surface of only 1,811 square inches.

The cost of this wonder of the age is 60,000 dollars.

Description of the Figure.—The following description of a section of Lord Rosse's telescope, *Fig.* 224, though not so perfect as could be desired, is the best we could obtain. It exhibits a view of the inside of the eastern wall, with the tube, and machinery by which it is moved. A is the mason-work on the ground; B the universal joint, which allows the tube to turn in all directions; C the speculum in the tube; E the eyepiece through which the observer looks; F a pulley by which the tube is moved; H a chain attached to the pulley, and to the side of the tube; I a chain running to K, the counterpoise; L a lever connecting the chain M with the tube; Z another

FIG. 224.



Lord Rosse's Telescope.

chain which passes from the upper part of the tube over a pulley at W, (not seen,) and crosses to the opposite wall; X a railroad on which the speculum is drawn either to or from the tube. The dotted line H, shows the course of the weight R, as the tube rises or falls. The tube is moved from wall to wall by a ratchet wheel at R, which is turned by the lever O, on the circle N. the ends of which are fixed in the two walls.

91. CAMERA OBSCURA.—*Camera obscura strictly signifies a darkened chamber, because the room must be darkened, in order to observe its effects.*

To witness the phenomena of this instrument, let a room be closed in every direction, so as to exclude the light. Then from an aperture, say of an inch in diameter, admit a single beam of light, and the images of external things, such as the trees and houses, and persons walking the streets, will be seen inverted on the wall opposite to where the light is admitted, or on a screen of white paper, placed before the aperture.

92. The reason why the image is inverted will be obvious, when it is remembered that the rays proceeding from the extremities of the object must converge in order to pass through the small aperture; and as the rays of light always proceed in

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91. What does camera obscura mean? Describe the phenomena of the camera obscura. 92. Why is the image formed by the camera obscura inverted? How may an outline of the image formed by the camera obscura be taken? Describe the revolving camera obscura.

the figure, the light reflected from A, will pass between the partitions, C and I, to the mirror, and will reflect the image of the book to Z, where it will appear so distinct and tangible, that a person looking through the opening at X, will have no doubt that it is a real book, and will be much astonished to find, when he puts out his hand to take it, that it has no substance, and that his hand will pass through it, as though it was nothing but a shadow, which he can not at first be made to believe is the case.

50. *Heat Produced by a Concave Mirror.*—The concave mirror having the property of converging the rays of light, is equally efficient in concentrating the rays of heat, either separately or with the light. When, therefore, such a mirror is presented to the rays of the sun, it brings them to a focus, so as to produce degrees of heat in proportion to the extent and perfection of its reflecting surface. A metallic mirror of this kind, of only four or six inches in diameter, will fuse metals, set wood on fire, &c.

51. *Experiment with a Hot Ball.*—As the parallel rays of heat or light are brought to a focus at the distance of one quarter of the diameter of the sphere, of which the reflector is a section, so if a luminous or heated body be placed at this point, the rays from such body passing to the mirror will be reflected from all parts of its surface, in parallel lines; and the rays so reflected by the same law, will be brought to a focus by another mirror standing opposite to this.

52. Suppose a red-hot ball to be placed in the principal focus of the mirror A, *Fig.* 198, the rays of heat and light proceeding from it will be reflected in the parallel lines 1, 2, 3, &c. The reason of this is the same as that which causes parallel rays, when falling on the mirror, to be converged to a focus. The angles of incidence being equal to those of reflection, it makes no difference in this respect, whether the rays pass to or from the focus. In one case, parallel incident rays from the sun, are concentrated by reflection; and in the other, incident diverging rays, from the heated ball, are made parallel by reflection.

The rays, therefore, flowing from the hot ball to the mirror

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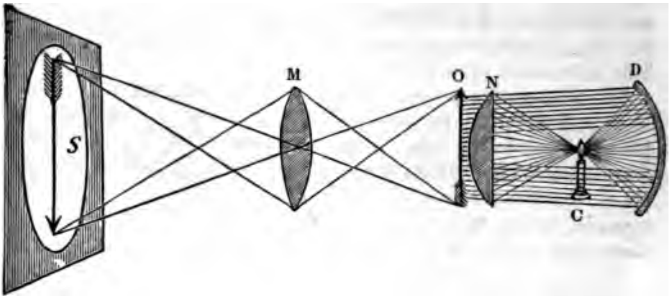
50. Will the concave mirror concentrate the rays of heat, as well as those of light? 51. Suppose a luminous body be placed in the focus of a concave mirror, in what direction will its rays be reflected? 52. Explain Fig 198, and show why the rays from the focus of A are concentrated in the focus B. What curious experiments may be made by two concave mirrors placed opposite to each other by a hot ball? How may it be shown that heat and light are distinct principles?

form in miniature a most perfect and beautiful picture of the landscape in that direction. Then, by making the reflector revolve, another portion of the landscape may be seen, and thus the objects, in all directions, can be viewed at K without changing the place of the instrument.

MAGIC LANTERN.

93. *The Magic Lantern is a microscope on the same principle as the solar microscope.*—But instead of being used to magnify natural objects, it is commonly employed for amusement, by casting the shadows of small transparent paintings done on glass, upon a screen placed at a proper distance.

FIG. 227.



Magic Lantern.

Let a candle C, *Fig.* 227, be placed on the inside of a box or tube, so that its light may pass through the plano-convex lens N, and strongly illuminate the object O. This object is generally a small transparent painting on a slip of glass, which slides through an opening in the tube. In order to show the figures in the erect position, these paintings are inverted, since their shadows are again inverted by the refraction of the convex lens M.

In some of these instruments there is a concave mirror, D, by which the object O, is more strongly illuminated than it would be by the lamp alone. The object is magnified by the double-convex lens, M, which is movable in the tube by a screw, so

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93. What is the magic lantern? For what purpose is this instrument employed? *Describe* the construction and effect of the magic lantern.

that its focus can be adjusted to the required distance. Lastly, there is a screen of white cloth, placed at the proper distance, on which the image or shadow of the picture, is seen greatly magnified.

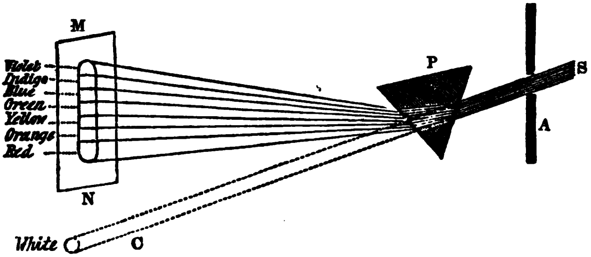
The pictures being of various colors, and so transparent, that the light of the lamp shines through them, the shadows are also of various colors, and thus soldiers and horsemen are represented in their proper costume.

CHROMATICS, OR THE PHILOSOPHY OF COLORS.

94. We have thus far considered light as a simple body, and have supposed that all its parts were equally refracted, in its passage, through the several lenses described. But it will now be shown that light is a compound body, and that each of its rays, which to us appear white, is composed of several colors, and that each color suffers a different degree of refraction, when the rays of light pass through a piece of glass, of a certain shape. This was a discovery of Sir Isaac Newton.

95. Solar Spectrum.—If a ray, proceeding from the sun, be admitted into a darkened chamber, through an aperture in the window shutter, and allowed to pass through a triangular shaped piece of glass, called a *prism*, the light will be decomposed, and instead of a spot of white, there will be seen, on the opposite wall, a most brilliant display of colors, including all those seen in the rainbow.

FIG. 228.



Solar Spectrum.

Suppose S, *Fig.* 228, to be a ray from the sun, admitted through the window shutter A, in such a direction as to fall on

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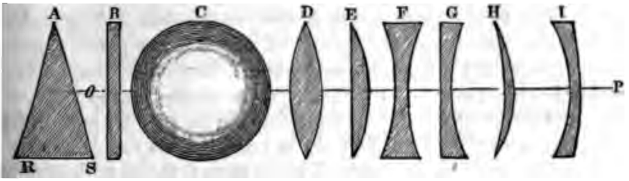
94. Who made the discovery, that light is a compound substance? 95. In what manner, and by what means, is light decomposed?

FIG. 200.



Lenses of Various Forms.

A *plano-convex lens*, E, is bounded by a convex surface on one side, and a plane one on the other.

A *double-concave lens*, F, is bounded by two concave spherical surfaces, opposite to each other.

A *plano-concave lens*, G, is bounded by a plane surface on one side and a concave one on the other.

A *meniscus*, H, is bounded by one concave, and one convex spherical surface, which two surfaces meet at the edge of the lens.

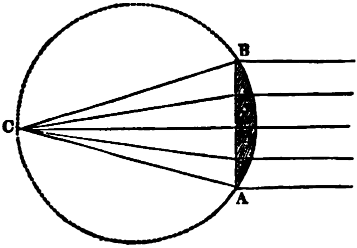
A *concavo-convex lens*, I, is bounded by a concave, and convex surface, but which diverge from each other, if continued.

The effects of the prism on the rays of light will be shown in another place. The refraction of the *plane* glass bends the parallel rays of light equally toward the perpendicular, as already shown. The *sphere* is not often employed as a lens, since it is inconvenient in use.

CONVEX LENS.

56. *The effect of the convex lens, by increasing the visual angle, is to magnify all objects seen through it.*

FIG. 201.



Plano-Convex Lens.

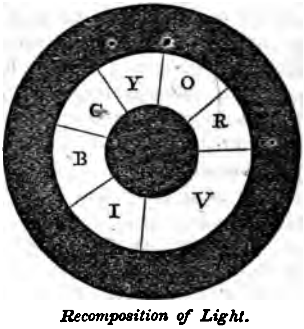
Focal Distance.—The focal distances of convex lenses, depend on their degrees of convexity. The focal distance of a *single*, or plano-convex lens, is the diameter of a sphere, of which it is a section.

If the whole circle, *Fig.* 201, be considered the circumference of a sphere, of which the plano-convex lens B A, is a served around the point of contact between the two surfaces, and their number may be increased or diminished by the degrees of pressure. Two pieces of common looking-glass, pressed together with the fingers, will display most of the prismatic colors.

98. A variety of substances, when thrown into the form of the triangular prism, will decompose the rays of light, as well as a prism of glass. A very common instrument for this purpose is made by putting together three pieces of plate glass, in form of a prism. The ends may be made of wood, and the edges cemented with putty, so as to make the whole water-tight. When this is filled with water, and held before a sunbeam, the solar spectrum will be formed, displaying the same colors, and in the same order, as that above described.

99. *Recomposition of Light by a Circle.*—On this subject, a curious and satisfactory experiment may be made by means of a dark center, and circle, with divisions between them, representing the proportions of the prismatic rays, and colored to imitate them. The letters, *Fig.* 229, show the different colors of the seven rays, and the spaces they severally occupy.

FIG. 229.



Recomposition of Light.

100. Now if this card, thus colored, be placed on a spindle and made to turn rapidly, the seven colors will entirely disappear, and a dull white only will be presented to the eye, instead of them.

101. *Explanation.*—Any color remains for an instant on the eye after it is covered, or removed, and hence a fire-brand whirled rapidly, appears a circle of fire. Two revolving colors will thus be so blended as to seem a medium between them; thus if all the colors on the card are covered, except the yellow and red, they will appear orange. And if all the prismatic tints are blended, whether in the form of powders, or proportionate, colored, revolving surfaces, they produce white.

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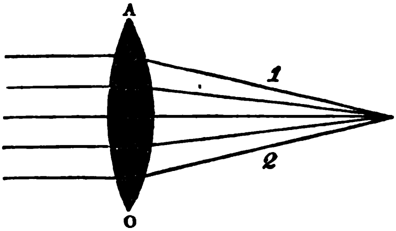
98. Of what substances may prisms be formed, besides glass? 99. For what are the divisions of the circle, Fig. 229, intended? What is said to be the effect when this card is revolved on a spindle? 100. What color is said to be produced when all the prismatic tints are mixed or revolved? 101. What is the explanation?

Fig. 203, would become convergent, instead of parallel, because the same refractive power which would render divergent rays parallel, would make parallel rays convergent, and converging rays still more convergent.

FIG. 203.



Diverging Rays.

Thus the pencils of converging rays, *Fig.* 204, are rendered still more convergent by their passage through the lens, and are therefore brought to a focus nearer the lens, in proportion to their previous convergence.

The eyeglasses of spectacles for old people are double-convex lenses, more or less spherical, according to the age of the person, or the magnifying power required.

60. Burning Glass.—The common burning glasses, which are used for lighting cigars, and sometimes for kindling fires, are also convex lenses. Their effect is to concentrate to a focus, or point, the heat of the sun which falls on their whole surface; and hence the intensity of their effects is in proportion to the extent of their surfaces, and their focal lengths.

61. Visual Angle.—It has been explained, that the reason why the convex mirror diminishes the images of objects is, that the rays which come to the eye from the extreme parts of the object are rendered less convergent by reflection, from the convex surface, and that in consequence, the angle of vision is made more acute. (41.)

62. Now, the refractive power of the convex lens has exactly the contrary effect, since by converging the rays flowing from the extremities of an object, the visual angle is rendered more obtuse, and therefore all objects seen through it appear magnified.

63. Suppose the object A, Fig. 205, appears to the naked eye of the length represented in the drawing. Now, as the rays coming from each end of the object, form by their convergence at the eye, the *visual angle*, or the angle under which the object is seen, and we call objects large or small in propor-

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60. What kind of a lens is a burning glass? 61. What is the visual angle? 62. What is the effect of the convex lens on the visual angle? 63. Why does the same object, when at a distance, appear smaller than when near? Why does an object appear larger through the convex lens than otherwise?

stated, (103,) that from a single globe, the whole solar spectrum is not seen in the same position, but that the different colors are seen from different places. Suppose, then, that a ray of light from the sun S, on entering the globe at A is separated into its primary colors, and at the same time the red ray, which is the least refrangible, is refracted in the line from A to B. From the second, or inner surface of the drop, it would be reflected to C, the angle of reflection being equal to the angle of incidence. On passing out of the drop, its refraction at C, would be just equal to the refraction of the incident ray at A, and therefore the red ray would fall on the eye at E. All the other colored rays would follow the same law, but because the angles of incidence and those of reflection are equal, and because the colored rays are separated from each other by unequal refraction, it is obvious, that if the red ray enters the eye at E, none of the other colored rays could be seen from the same point.

105. From this it is evident, that if the eye of the spectator is moved to another position, he will not see the red ray coming from the same drop of rain, but only the blue, and if to another position, the green, and so of all the others. But in a shower of rain, there are drops at all heights and distances, and though they perpetually change their places, in respect to the sun and the eye, as they fall, still there will be many which will be in such a position as to reflect the red rays to the eye, and as many more to reflect the yellow rays, and so of all the other colors.

106. This will be made obvious by *Fig.* 231, where, to avoid confusion, we will suppose that only three drops of rain, and, consequently, only three colors, are to be seen.

The numbers 1, 2, 3, are the rays of the sun, proceeding to the drops A B C, and from which these rays are reflected to the eye, making different angles with the horizontal line H, because one colored ray is refracted more than another. Now, suppose the red ray only reaches the eye from the drop A, the green from the drop B, and the violet from the drop C, then the spectator would see a minute rainbow of three colors. But during a shower of rain, all the drops which are in the position of A, in respect to the eye, would send forth red rays, and no

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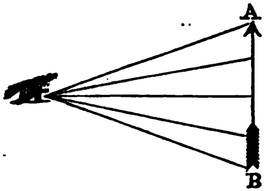
104. Explain Fig. 230, and show the different refractions, and the reflection concerned in forming the rainbow. In the case supposed, why will only the red ray meet the eye? 105. Suppose a person looking at the rainbow moves his eye, will he see the same colors from the same drop of rain? 106. Explain Fig. 231, and show why we see different colors from different drops of rain. Do several persons see the same rainbow at the same time? Explain the reason of this.

rectly opposite to that of the convex. In other terms, by a concave lens, parallel rays are rendered diverging, converging rays have their convergence diminished, and diverging rays have their divergence increased, according to the concavity of the lens.

These glasses, therefore, exhibit things smaller than they really are, for by diminishing the convergence of the rays coming from the extreme points of an object, the visual angle is rendered more acute, and hence the object appears diminished by this lens, for the opposite reason, that it is increased by the convex lens. This will be made plain by the two following diagrams.

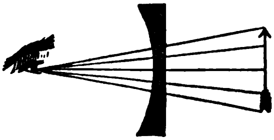
Suppose the object A B, *Fig.* 207, to be placed at such a distance from the eye, as to give the rays flowing from it, the degrees of convergence represented in the figure, and suppose that the rays enter the eye under such an angle as to make the object appear two feet in length.

FIG. 207.



Natural Vision.

FIG. 208.



Plano-Concave Lens.

Now, the length of the same object, seen through the concave lens, *Fig.* 208, will appear diminished, because the rays coming from it are bent outward, or made less convergent by refraction, as seen in the figure, and consequently the visual angle is more acute than when the same object is seen by the naked eye. Its length, therefore, will appear less in proportion as the rays are rendered less convergent.

The spectacle glasses of short-sighted people are concave lenses, by which the images of objects are formed further back in the eye than otherwise, as will be explained under the next article.

What effect does this lens have upon parallel, diverging, and converging rays? Why do objects appear smaller through this glass than they do to the naked eye? Explain Figs. 207 and 208, and show the reason why the same object appears smaller through 208. What defect in the eye requires concave lenses?

108. To account for such a variety of colors as we see in different bodies, it is supposed that all substances, when made sufficiently thin, are transparent, and consequently, that they transmit through their surfaces, or absorb, certain rays of light, while other rays are thrown back, or reflected. Gold, for example, may be beat so thin as to transmit some of the rays of light, and the same is true of several of the other metals, which are capable of being hammered into thin leaves, It is therefore most probable, that all the metals, could they be made sufficiently thin, would permit the rays of light to pass through them. Most, if not quite all mineral substances, though in the mass they may seem quite opaque, admit the light through their edges, when broken, and almost every kind of wood, when made no thinner than writing paper, becomes translucent. Thus we may safely conclude, that every substance with which we are acquainted, will admit the rays of light, when made sufficiently thin.

109. *Transparent Substances.*—Transparent, colorless substances, whether solid or fluid, such as glass, water, or mica, reflect and transmit light of the same color; that is, the light seen through these bodies, and reflected from their surfaces, is white. This is true of all transparent substances under ordinary circumstances; but if their thickness be diminished to a certain extent, these substances will both reflect and transmit colored light of various hues, according to their thickness. Thus, the thin plates of mica, which are left on the fingers after handling that substance will reflect prismatic rays of various colors.

110. From such phenomena, Sir Isaac Newton concluded, that air, when below the thickness of *half a millionth of an inch*, ceases to reflect light; and also, that water, when below the thickness of *three-eighths of a millionth of an inch*, ceases to reflect light. But that both air and water, when their thickness is in a certain degree above these limits, reflect all the colored rays of the spectrum.

111. From a great variety of experiments on this subject, Sir Isaac Newton concludes that the transparent parts of bodies, according to the sizes of their transparent pores, reflect rays of one color, and transmit those of another, for the same reason

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108. How is the variety of colors accounted for, by considering all bodies transparent? 109 What is said of the reflection of colored light by transparent substances? What substance is mentioned. as illustrating this fact? 110. What is the conclusion of Sir Isaac Newton, concerning the tenuity at which water and air cease to reflect light? 111. What is said of the porous nature of the solid bodies?

that thin plates, or minute particles of air, water, and some other substances, reflect certain rays, and absorb or transmit others, and that this is the cause of all their colors.

CHAPTER XII.

ASTRONOMY.

112. THIS term is compounded of the Greek *astra*, the stars, and *nomos* a law; and hence signifies the laws of the celestial bodies.

Astronomy is that science which treats of the motions and appearance of the heavenly bodies; accounts for the phenomena which these bodies exhibit to us; and explains the laws by which their motions, or apparent motions, are regulated.

Astronomy is divided into *Descriptive*, *Physical*, and *Practical.*

Descriptive astronomy demonstrates the magnitudes, distances, and densities of the heavenly bodies, and explains the phenomena dependent on their motions, such as the change of seasons, and the vicissitudes of day and night.

Physical astronomy explains the theory of planetary motion, and the laws by which this motion is regulated and sustained.

Practical astronomy details the description and use of astronomical instruments, and develops the nature and application of astronomical calculations.

The heavenly bodies are divided into three distinct classes, or systems, namely, *the solar system*, consisting of the sun, moon, and planets; the system of the *fixed stars;* and the system of the *comets.*

THE SOLAR SYSTEM.

113. *The Solar System consists of the Sun, and forty-two other bodies, including the satellites, which revolve around him at various distances, and in various periods of time.*

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112. What is astronomy? How is astronomy divided? What does descriptive astronomy teach? What is the object of physical astronomy? What is practical astronomy? How are the heavenly bodies divided? 113. Of what does the solar system consist?

These bodies, being perpetually in motion, are called *planets*, from a Greek word signifying wanderers, and they are distinguished with reference to their centers of revolution, into *primary* and *secondary*.

114. The *Primary* planets are those which revolve around the sun as their proper center. These are twelve in number; that nearest the sun being Mercury, the others follow in succession, thus: Venus, Earth, Mars, Vesta, Ceres, Pallas, Juno, Jupiter, Saturn, Herschel or Uranus, and Neptune.

115. The *Secondary* planets are those which move round the primaries, as these move round the sun. Of these, there are nineteen, called also *moons*, or *satellites*. These, as we shall see, like their primaries, complete their revolutions at various periods of time.

PRIMARY PLANETS.

116. The following tabular view of the primary planets exhibits their respective diameters; their distances from the sun; the periods of their revolutions round the sun; the periods of their revolutions round their axes, where this is known; and their hourly motion through their several orbits.

Names of the Planets.	Diameter in English miles.	Distances from the Sun in English miles.	Revolution round the Sun.	Periods of revolution on their own axes.			Hourly motion in miles.
			Days.	Days.	Hrs.	M.	
Mercury,	3,224	37,000,000	88	15	0	5	110,000
Venus,	7,687	68,000,000	224¾	0	23	21	80,000
The Earth,	7,912	95,000,000	365¼	1	0	0	68,000
Mars,	4,189	144,000,000	687	1	0	39	55,000
Vesta,	238	225,000,000	1,335	Unknown.			45,000
Ceres,	163	260,000,000	1,681				41,000
Pallas,	80	266,000,000	1.680				41,000
Juno,	1.425	275,000,000	2,008	1	3	0	45,000
Jupiter,	89.170	490,000,000	4.330½	0	9	56	36,000
Saturn,	79,042	900,000,000	10,746¾	0	10	16	22,000
Herschel,	35.112	1,800,000,000	30,637¼	0	7	0	15,000
Neptune,	35,000	2,850,000,000	166 ys.	Unknown.			Unk'wn.

Note. The above table, taken from the last London (Prof. Hoblyn's) edition of our Philosophy, is believed to be correct, according to the most recent observations. It will be seen that in the descriptions of the planets, round numbers are generally employed, as being more easily remembered—also that the periodic revolutions of the planets are given in years, days and hours, instead of days only, as in the table.

117. *A Year, what.*—A year consists of the time which it takes a planet to perform one complete revolution through its

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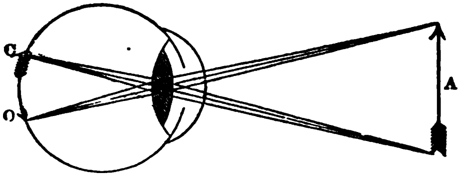
114. What are the bodies called, which revolve around the Sun as a center? 115 What are those planets called which revolve around these primaries as a center? 116. In what order are the several planets situated in respect to the Sun? How long does it take each planet to make its revolution around the Sun? 117. What is a year?

FIG. 212.



Inversion of Objects.

The actual position of the vertical object A, *Fig.* 212, as painted on the retina, is therefore such as is represented by the figure. The rays from its upper extremity, coming in divergent lines, are converged by the crystaline lens, and fall on the retina at O; while those from its lower extremity, by the same law, fall on the retina at C, the rays crossing each other as they pass the humors of the eye.

69. In order that vision may be perfect, it is necessary that the images of objects should be formed precisely on the retina, and consequently, if the refractive power of the eye be too small, or too great, the image will not fall exactly on the seat of vision, but will be formed either before, or tend to form behind it. In both cases, perhaps, an outline of the object may be visible, but it will be confused and indistinct.

70. *Cornea too Prominent.*—If the cornea is too convex, or prominent, the image will be formed before it reaches the retina, for the same reason, that of two lenses, that which is most convex will have the least focal distance. Such is the defect in the eyes of persons who are short-sighted, and hence the necessity of their bringing objects as near the eye as possible, so as to make the rays converge at the greatest distance behind the crystaline lens.

The effect of uncommon convexity in the cornea on the rays of light, is shown at *Fig.* 213, where it will be observed that the image, instead of being formed on the retina R, is suspended in the vitreous humor, in consequence of there being too great a refractive power in the eye. It is hardly necessary to say, that in this case, vision must be very imperfectly performed.

This defect of sight is remedied by spectacles, the glasses of

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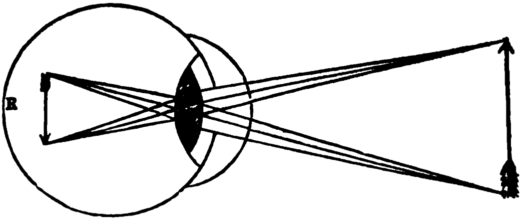
69. Suppose the refractive power of the eye is too great, or too little, why will vision be imperfect? 70. If the cornea is too convex, where will the image be formed? How is the sight improved, when the cornea is too convex? How do such lenses act to improve the sight?

FIG. 213.

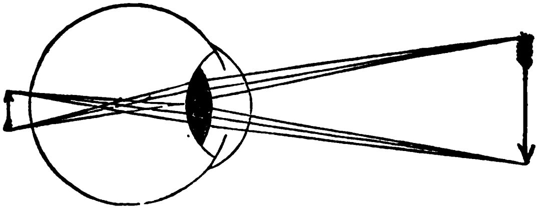


Cornea too Convex.

which are concave lenses. Such glasses, by rendering the rays of light less convergent, before they reach the eye, counteract the too great convergent power of the cornea and lens, and thus throw the image on the retina.

71. *Cornea too Flat.*—If, on the contrary, the humors of the eye, in consequence of age, or any other cause, have become less in quantity than ordinary, the eyeball will not be sufficiently distended, and the cornea will become too flat, or not sufficiently convex, to make the rays of light meet at the proper place, and the image will therefore tend to be formed beyond the retina, instead of before it, as in the other case. Hence, aged people, who labor under this defect of vision, can not see distinctly at ordinary distances, but are obliged to remove the object as far from the eye as possible, so as to make its refractive power bring the image within the seat of vision.

G. 214.



Cornea too Flat.

The defect arising from this cause is represented by *Fig.* 214,

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71. Where do the rays tend to meet when the cornea is not sufficiently convex? How is vision assisted when the eye wants convexity? How do convex lenses help the sight of aged persons?

where it will be observed that the image is formed behind the retina, showing that the convexity of the cornea is not sufficient to bring the image within the seat of distinct vision. This imperfection of sight is common to aged persons, and is corrected in a greater or less degree by double-convex lenses, such as the common spectacle glasses. Such glasses, by causing the rays of light to converge, before they meet the eye, assist the refractive power of the crystaline lens, and thus bring the focus, or image, within the sphere of vision.

72. *Why we see Objects Erect.*—It has been considered difficult to account for the reason why we see objects erect, when they are painted on the retina inverted, and many learned theories have been written to explain this fact. But it is most probable that this is owing to habit, and that the image, at the bottom of the eye, has no relation to the terms above and below, but to the position of our bodies, and other things which surround us. The term *perpendicular*, and the idea which it conveys to the mind, is merely relative; but when applied to an object supported by the earth, and extending toward the skies, we call the body *erect*, because it coincides with the position of our own bodies, and we see it erect for the same reason. Had we been taught to read by turning our books upside down, what we now call the upper part of the book would have been its under part, and that reading would have been as easy in that position as in any other, is plain from the fact that printers read their type, when set up, as readily as they do its impressions on paper.

ANGLE OF VISION.

73. This subject, partly explained, needs further illustration. *The angle under which the rays of light, coming from the extremities of an object, cross each other at the eye, bears a proportion directly to the length, and inversely to the distance of the object.*

Suppose the object A B, *Fig.* 215, to be four feet long, and to be placed ten feet from the eye, then the rays flowing from its extremities, would intersect each other at the eye, under a given angle, which will always be the same when the object is at the same distance. If the object be gradually moved toward

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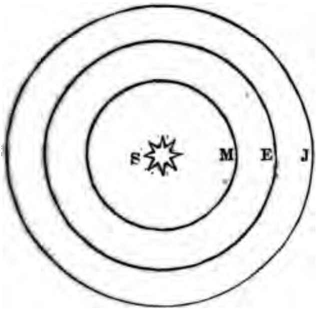
72. Why do we see things erect, when the images are inverted on the retina? 73. What is the visual angle? How may the visual angle of the same object be increased or diminished? When do objects of different magnitudes form the same visual angle? Explain Fig. 215.

Earth, and consequently they are called *inferior* planets. The orbits of all the other planets are without, or exterior to that of the Earth, and these are called *superior* planets.

126. That the orbits of Mercury and Venus are within that of the Earth, is evident from the circumstance that they are never seen in opposition to the Sun, that is, they never appear in the west when the Sun is in the east. On the contrary, the orbits of all the other planets are proved to be outside of the Earth's, since these planets are sometimes seen in opposition to the Sun.

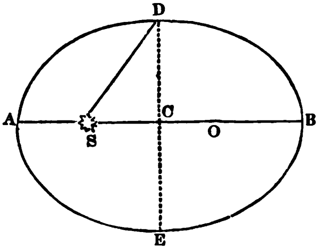
This will be understood by *Fig.* 232, where suppose S to be the Sun, M the orbit of Mercury or Venus, E the orbit of the Earth, and J that of Jupiter. Now, it is evident, that if a spectator be placed any where on the Earth's orbit, as at E, he may sometimes see Jupiter in opposition to the Sun, as at J, because then the spectator would be between Jupiter and the Sun. But the orbit of Venus, being surrounded by that of the Earth, she never can come in opposition to the Sun, or in that part of the heavens opposite to him, as seen by us, because our Earth never passes between her and the Sun.

FIG. 232.



Orbits of the Planets.

FIG. 233.



Elliptical Orbit.

127. *Orbits Elliptical.*—It has already been stated, that the orbits of the planets are elliptical, (124,) and that, consequently, these bodies are sometimes nearer the Sun than at others. An

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126. How is it proved that the inferior planets are within the Earth's orbit, and the superior ones without it? Explain Fig. 232, and show why the inferior planets never can be in opposition to the Sun. 127. What are the shapes of the planetary orbits? What is meant by perihelion? What by aphelion?

75. But when the object is near us, and seen with the naked eye, we then judge of the magnitude by our experience, and not entirely by the visual angle. Thus, the three arrows, A E M, *Fig.* 215, all of them make the same angle on the eye, and yet we know, by further examination, that they are all of different lengths. And so the two arrows, A B, and C D, though seen under different visual angles, will appear of the same size, because experience has taught us that this difference depends only on the comparative distance of the two objects.

76. As the visual angle diminishes inversely in proportion as the distance of the object increases, so when the distance is so great as to make the angle too minute to be perceptible to the eye, then the object becomes invisible. Thus, when we watch an eagle flying from us, the angle of vision is gradually diminished, until the rays proceeding from the bird form an image on the retina too small to excite sensation, and then we say the eagle has flown out of sight.

The same principle holds with respect to objects which are near the eye, but are too small to form an image on the retina which is perceptible to the senses. Such objects to the naked eye, are of course invisible, but when the visual angle is enlarged, by means of the convex lens, they become visible; that is, their images on the retina excite sensation.

77. Size of the Image on the Retina.—The actual size of an image on the retina, capable of exciting sensation, and consequently of producing vision, may be too small for us to appreciate by any of our other senses; for when we consider how much smaller the image must be than the object, and that a human hair can be distinguished by the naked eye at the distance of twenty or thirty feet, we must suppose that the retina is endowed with the most delicate sensibility, to be excited by a cause so minute. It has been estimated that the image of a man, on the retina, seen at the distance of mile, is not more than the five thousandth part of an inch in length.

78. Indistinct Vision.—On the contrary, if the object be brought too near the eye, its image becomes confused and indistinct, because the rays flowing from it, fall on the crystaline lens in a state too divergent to be refracted to a focus on the retina.

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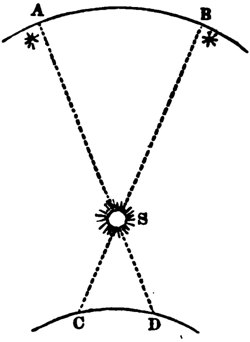
75. How do we judge of the comparative size of objects near us? 76. When does a retreating object become invisible to the eye? How does a convex lens act to make us see objects which are invisible without it? 77. What is said of the actual size of an image on the retina? 78. Why are objects indistinct when brought too near the eye?

S, *Fig.* 234, is the Sun, A B, a part of the circle of the ecliptic, and C D, a part of the Earth's orbit. Now if a spectator be placed at C, he will see the Sun in that part of the ecliptic marked by B, but when the Earth moves in her annual revolution to D, the spectator will see the Sun in that part of the heavens marked by A; so that the motion of the Earth in one direction, will give the Sun an apparent motion in the contrary direction.

FIG. 234.



Zodiac.

131. CONSTELLATIONS.—A sign or *constellation*, is a collection of fixed stars, and as we have already seen, the Sun appears to move through the twelve signs of the zodiac every year. Now, the Sun's place in the heavens, or zodiac, is found by his apparent conjunction, or nearness to any particular star in the constellation. Suppose a spectator at C, *Fig.* 234, observes the Sun to be nearly in a line with the star at B, then the Sun would be near a particular star in a certain constellation. When the Earth moves to D, the Sun's place would assume another direction, and he would seem to have moved into another constellation, and near the star A.

132. Each of the 12 signs of the zodiac is divided into 30 smaller parts, called degrees; each degree into 60 equal parts, called minutes, and each minute into 60 parts, called seconds.

The division of the zodiac into signs, is of very ancient date, each sign having also received the name of some animal, or thing, which the constellation, forming that sign, was supposed to resemble. It is hardly necessary to say, that this is chiefly the result of imagination, since the figures made by the places of the stars, never mark the outlines of the figures of animals, or other things. This is, however, found to be the most convenient method of finding any particular star at this day, for among astronomers, any star, in each constellation, may be designated by describing the part of the animal in which it is

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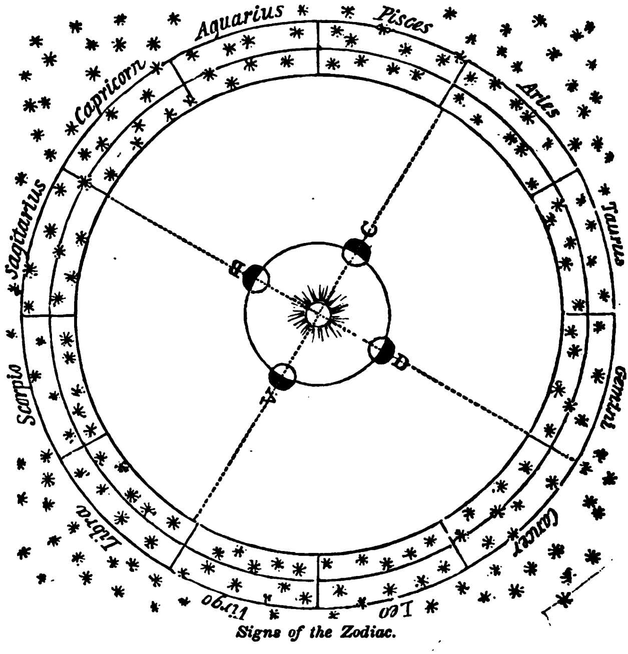
131. What is a constellation, or sign? How is the Sun's apparent place in the heavens found? 132. Into how many parts are the signs of the zodiac divided, and what are these parts called? Is there any resemblance between the places of the stars, and the figures of the animals after which they are called? Explain why this is a convenient method of finding any particular star in a sign.

situated. Thus, by knowing how many stars belong to the constellation Leo, or the Lion, we readily know what star is meant by that which is situated on the Lion's ear or tail.

133. *Names of the Signs.*—The names of the 12 signs of the zodiac are, Aries, Taurus, Gemini, Cancer, Leo, Virgo, Libra, Scorpio, Sagittarius, Capricorn, Aquarius, and Pisces. The common names, or meaning of these words, in the same order, are, the Ram, the Bull, the Twins, the Crab, the Lion, the Virgin, the Scales, the Scorpion, the Archer, the Goat, the Waterer, and the Fishes.

FIG. 235.



Signs of the Zodiac.

134. The twelve signs of the zodiac, together with the Sun, and the earth revolving around him, are represented at *Fig.* 235. When the Earth is at A, the Sun will appear to be just

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133. What are the names of the twelve signs? 134. Explain why the Sun will be in the beginning of Aries when the Earth is at A, Fig. 235.

entering the sign Aries, because then, when seen from the Earth, he ranges toward certain stars at the beginning of that constellation. When the Earth is at C, the Sun will appear in the opposite part of the heavens, and therefore in the beginning of Libra. The middle line, dividing the circle of the zodiac into equal parts, is the line of the ecliptic. 0

135. Density of the Planets.—Astronomers have no means of ascertaining whether the planets are composed of the same kind of matter as our Earth, or whether their surfaces are clothed with vegetables and forests, or not. They have, however, been able to ascertain the densities of several of them, by observations on their mutual attraction. By *density*, is meant compactness, or the quantity of matter in a given space. (72.) When two bodies are of equal bulk, that which weighs most, has the greatest density. It was shown, while treating of the *properties of bodies*, that substances attract each other in proportion to the quantities of matter they contain. (132.) If, therefore, we know the dimensions of several bodies, and can ascertain the proportion in which they attract each other, their quantities of matter, or densities, are easily found.

136. Thus, when the planets pass each other in their circuits through the heavens, they are often drawn a little out of the lines of their orbits by mutual attraction. As bodies attract in proportion to their quantities of matter, it is obvious that the small planets, if of the same density, will suffer greater disturbance from this cause, than the large ones. But suppose two planets, of the same dimensions, pass each other, and it is found that one of them is attracted twice as far out of its orbit as the other, then, by the known laws of gravity, it would be inferred, that one of them contained twice the quantity of matter that the other did, and therefore that the density of the one was twice that of the other.

By calculations of this kind, it has been found, that the density of the Sun is but a little greater than that of water, while Mercury is more than nine times as dense as water, having a specific gravity nearly equal to that of lead. The Earth has a density about five times greater than that of the Sun, and a little less than half that of Mercury. The densities of the other planets seem to diminish in proportion as their distances from

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135. How has the density of the planets been ascertained? What is meant by density? In what proportion do bodies attract each other? 136. How are the densities of the planets ascertained? What is the density of the Sun, of Mercury, and of the Earth? In what proportions do the densities of the planets appear to diminish?

the Sun increase, the density of Saturn, one of the most remote of planets, being only about one-third that of water.

THE SUN.

137. *The Sun is the center of the solar system, and the great dispenser of heat and light to all the planets. Around the Sun all the planets revolve, as around a common center, he being the largest body in our system, and, so far as we know, the largest in the universe.*

Distance of the Sun.—The distance of the Sun from the Earth is 95 millions of miles, and his diameter is estimated at 887,000 miles. Our globe, when compared with the magnitude of the Sun, is a mere point, for his bulk is about *thirteen hundred thousand* times greater than that of the Earth. Were the Sun's center placed in the center of the Moon's orbit, his circumference would reach two hundred thousand miles beyond her orbit in every direction, thus filling the whole space between us and the moon, and extending nearly as far beyond her as she is from us. A traveler, who should go at the rate of 90 miles a day, would perform a journey of nearly 33,000 miles in a year, and yet it would take such a traveler more than 80 years to go round the circumference of the Sun. A body of such mighty dimensions, hanging on nothing, it is certain, must have emanated from an Almighty power.

The Sun appears to move around the Earth every 24 hours, rising in the east, and setting in the west. This motion, as will be proved in another place, is only apparent, and arises from the diurnal revolution of the Earth.

138. *Diurnal Revolution of the Sun.*—The Sun, although he does not, like the planets, revolve in an orbit, is, however, not without motion, having a revolution around his own axis, once in 25 days and 10 hours. Both the fact that he has such a motion, and the time in which it is performed, have been ascertained by the spots on his surface. If a spot is seen, on a revolving body, in a certain direction, it is obvious, that when the same spot is again seen, in the same direction, that the body has made one revolution. By such spots the diurnal revolutions of the planets, as well as the Sun, have been determined.

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137. Where is the place of the Sun in the solar system? What is the distance of the Sun from the Earth? What is the diameter of the Sun? Suppose the center of the Sun and that of the Moon's orbit to be coincident, how far would the Sun extend beyond the Moon's orbit? 138. How is it proved that the Sun has a motion around his own axis? How often does the Sun revolve?

139. SPOTS ON THE SUN.—Spots on the Sun, seem first to have been observed in the year 1611, since which time they have constantly attracted attention, and have been the subject of investigation among astronomers. These spots change their appearance as the Sun revolves on his axis, and become greater or less, to an observer on the Earth, as they are turned to, or from him; they also change in respect to real magnitude and number; one spot, seen by Dr. Herschel, was estimated to be more than six times the size of our Earth, being 50,000 miles in diameter. Sometimes forty or fifty spots may be seen at the same time, and sometimes only one. They are often so large as to be seen with the naked eye; this was the case in 1816.

140. *Nature and Design of these Spots.*—In respect to the nature and design of these spots, almost every astronomer has formed a different theory. Some have supposed them to be solid opaque masses of scoriæ, floating in the liquid fire of the Sun; others, as satellites, revolving round him, and hiding his light from us; others, as immense masses, which have fallen on his disc, and which are dark-colored, because they have not yet become sufficiently heated. From these various theories we may infer that, at present, nothing certain is known of the nature and design of these spots.

MERCURY.

141. *Mercury*, the planet nearest the Sun, is about 3,000 miles in diameter, and revolves around him at the distance of 37 millions of miles. The period of his annual revolution is 88 days, and he turns on his axis once in about 15 hours.

No signs of an atmosphere have been observed in this planet. The Sun's heat at Mercury is about seven times greater than it is on the Earth, so that water, if nature follows the same laws there that she does here, can not exist at Mercury, except in the state of steam.

The nearness of this planet to the Sun, prevents his being often seen. He may, however, sometimes be observed just before the rising, and a little after the setting of the Sun. When seen after sunset, he appears a brilliant, twinkling star, showing

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139. When were the spots on the Sun first observed? What has been the difference in the number of spots observed? What was the size of the spots seen by Dr. Herschel? 140. What has been advanced concerning the nature of these spots? Have they been accounted for satisfactorily? 141. What is the diameter of Mercury, and what are his periods of annual and diurnal revolution? How great is the Sun's heat at Mercury? At what times is Mercury to be seen? What is a transit of Mercury?

a white light, which, however, is much obscured by the glare of twilight. When seen in the morning, before the rising of the Sun, his light is also obscured by the Sun's rays.

Mercury sometimes crosses the disc of the Sun, or comes between the Earth and that luminary, so as to appear like a small dark spot passing over the Sun's face. This is called the *transit* of Mercury.

VENUS.

142. *Venus* is the other planet, whose orbit is within that of the Earth. Her diameter is about 8,000 miles, being somewhat larger than the Earth.

Her revolution around the Sun is performed in 224 days, at the distance of 68 millions of miles from him. She turns on her axis once in 23 hours, so that her day is a little shorter than ours. Her hourly motion in her orbit, is 80,000 miles.

Venus, as seen from the Earth, is the most brilliant of all the primary planets, and is better known than any nocturnal luminary except the Moon. When seen through a telescope, she exhibits the phases or horned appearance of the moon, and her face is sometimes variegated with dark spots.

143. This planet may often be seen in the day time, even when she is in the vicinity of the blazing light of the Sun. A luminous appearance around this planet, seen at certain times, proves that she has an atmosphere. Some of her mountains are several times more elevated than any on our globe, being from 10 to 22 miles high.

144. Venus sometimes makes a transit across the Sun's disc, in the same manner as Mercury, already described. The transits of Venus occur only at distant periods from each other. The last transit was in 1769, and the next will not happen until 1874. These transits have been observed by astronomers with the greatest care and accuracy, since it is by observations on them that the true distances of the Earth and planets from the Sun are determined.

145. *Motions and Phenomena of Venus.*—Sometimes Venus appears to recede from the Sun, and then approach him, and as her orbit is within that of the earth, her distance from us

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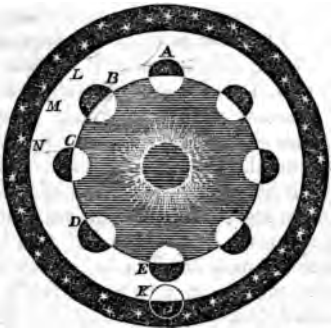
142. Where is the orbit of Venus, in respect to that of the Earth? What is the time of Venus' revolution round the Sun? How often does she turn on her axis? 143. What is said of the height of the mountains in Venus? 144. On what account are the transits of Venus observed with great care? 145. What is the least and greatest distance of Venus from the Earth? When is she in her *inferior*, and when in her *superior* conjunction with the Sun? Why is she invisible in those two positions?

varies from 27,000,000 to 163,000,000 of miles. When nearest the earth she forms her *inferior* conjunction with the Sun; that is, she is between us and him, and hence being overpowered with his light, is invisible. When at the greatest distance from us, she forms her *superior* conjunction with that luminary, and for the same reason again becomes invisible to us.

FIG. 236.



Phases of Venus.

These phenomena will be understood by the following explanations in connection with *Fig.* 236, which we quote from Dr. Dick.

146. Let the earth be supposed at K, then when Venus is in the position marked A, it is in a line with the Sun as seen from the earth, and is then in its *superior* conjunction, being in the remotest part of its orbit. When in this position, the whole of its enlightened hemisphere is toward the earth, but is invisible on account of the Sun's light. As it moves from A to B, being from west to east, which is called its *direct* motion, it begins to appear after sunset as the evening star. When at B, it appears among the stars at L, when it appears in a gibbous shape, nearly half its disc being luminous. When at C, it appears among the stars at M, nearly in the form of a half moon. At D, being at the point of its greatest elongation, it has the form of a half moon, and is seen among the stars at N. It now appears, for some time to be stationary, because moving nearly in a straight line toward the earth, its motion is not seen; when it again appears to move rapidly, but in a contrary direction from before, or, from east to west, during which it presents the form of a crescent. It now gradually becomes so overpowered by the Sun's rays as again to be invisible to the naked eye, and when arrived at E, forms her inferior conjunction with the Sun, and her nearest approach to the Earth.

147. In this position, Venus is 36,000,000 miles nearer the

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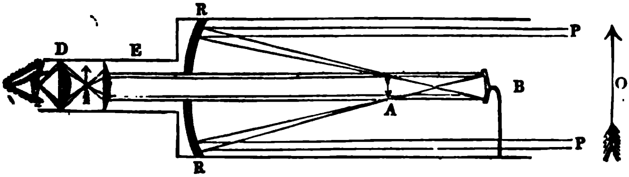
146. Describe by means of Fig. 236, the phases of Venus, from her superior to her inferior conjunction with the Sun.

Telescope

FIG. 223.



Reflecting Telescope.

aperture in the center of the great mirror, fall on the plano-convex lens E. By this lens they are refracted to a focus, and cross each other between E and D, and thus the image is again inverted, and brought to its original position, or in the position of the object. The rays then passing the second eyeglass, form the image of the object on the retina.

The large mirror in this instrument is fixed, but the small one moves backward and forward, by means of a screw, so as to adjust the image to the eyes of different persons. Both mirrors are made of a composition, consisting of several metals melted together.

87. One great advantage which the reflecting telescope possesses over the refracting, appears to be, that it admits of an eyeglass of shorter focal distance, and, consequently, of greater magnifying power. The convex object glass of the refracting instrument, does not form a perfect image of the object, since some of the rays are dispersed, and others colored by refraction. This difficulty does not occur in the reflected image from the metallic mirror of the reflecting telescope, and consequently it may be distinctly seen, when more highly magnified.

The instrument just described is called "*Gregory's telescope*," because some parts of the arrangement were invented by Dr. Gregory.

88. *Herschel's Telescope.*—In Dr. Herschel's grand telescope, the largest then constructed, the reflector was 48 inches in diameter, and had a focal distance of 40 feet. This reflector was three and a half inches thick, and weighed 2000 pounds. Now, since the focus of a concave mirror is at the distance of one-half the semi-diameter of the sphere, of which it is a sec-

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87. What is the advantage of the reflecting telescope in respect to the eyeglass? 88. What was the focal distance and diameter of the mirror in Dr. Herschel's great telescope? Where is the largest Herschel's telescope now in existence? What is the diameter and focal distance of the reflector of this telescope?

entering the sign Aries, because then, when seen from the Earth, he ranges toward certain stars at the beginning of that constellation. When the Earth is at C, the Sun will appear in the opposite part of the heavens, and therefore in the beginning of Libra. The middle line, dividing the circle of the zodiac into equal parts, is the line of the ecliptic. 0

135. Density of the Planets.—Astronomers have no means of ascertaining whether the planets are composed of the same kind of matter as our Earth, or whether their surfaces are clothed with vegetables and forests, or not. They have, however, been able to ascertain the densities of several of them, by observations on their mutual attraction. By *density*, is meant compactness, or the quantity of matter in a given space. (72.) When two bodies are of equal bulk, that which weighs most, has the greatest density. It was shown, while treating of the *properties of bodies*, that substances attract each other in proportion to the quantities of matter they contain. (132.) If, therefore, we know the dimensions of several bodies, and can ascertain the proportion in which they attract each other, their quantities of matter, or densities, are easily found.

136. Thus, when the planets pass each other in their circuits through the heavens, they are often drawn a little out of the lines of their orbits by mutual attraction. As bodies attract in proportion to their quantities of matter, it is obvious that the small planets, if of the same density, will suffer greater disturbance from this cause, than the large ones. But suppose two planets, of the same dimensions, pass each other, and it is found that one of them is attracted twice as far out of its orbit as the other, then, by the known laws of gravity, it would be inferred, that one of them contained twice the quantity of matter that the other did, and therefore that the density of the one was twice that of the other.

By calculations of this kind, it has been found, that the density of the Sun is but a little greater than that of water, while Mercury is more than nine times as dense as water, having a specific gravity nearly equal to that of lead. The Earth has a density about five times greater than that of the Sun, and a little less than half that of Mercury. The densities of the other planets seem to diminish in proportion as their distances from

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135. How has the density of the planets been ascertained? What is meant by density? In what proportion do bodies attract each other? 136. How are the densities of the planets ascertained? What is the density of the Sun, of Mercury, and of the Earth? In what proportions do the densities of the planets appear to diminish?

position by means of spirit levels. The crucibles were 10 hours in the furnace before the metal was sufficiently fluid to cast. The speculum weighed 3 tons—lost one-eighth of an inch in thickness by grinding.

Grinding.—The grinding was conducted under water, the moving power being a steam-engine of 3 horse power. The grinder is of cast iron with grooves in its face to retain the emery, and the two faces having a mutual motion, both became perfect, whatever might have been their inequalities. The polishing was done by means of a thin layer of pitch spread on the grinder, on which rouge was smeared in the form of paste with water. This process took six hours.

Construction of the Tube.—The tube is 56 feet long, made of boards and hooped with iron. On the inside at intervals of 8 feet, are iron rings to support the boards. Its diameter is 7 feet, the whole being easily moved in any direction by means of pulleys and levers, a universal joint at the lower end being designed for this purpose.

Wall of Support.—At a distance of 12 feet, on each side of the instrument is a brick wall, 72 feet long, 48 high on the outside, and 56 on the inside, ranging exactly on the meridianal line. These walls have rods of iron and wood passing from one to the other, for the support of the telescope, as it is turned in different directions.

The weight of the speculum and tube, including that of the bed on which it is sustained, is about 15 tons.

This being a reflecting telescope, the observer stands in a gallery at the upper end, and looks into the side of the great tube, where the observations are made by means of a reflecting surface of 4,071 square inches, while Herschel's great reflector had a surface of only 1,811 square inches.

The cost of this wonder of the age is 60,000 dollars.

Description of the Figure.—The following description of a section of Lord Rosse's telescope, *Fig.* 224, though not so perfect as could be desired, is the best we could obtain. It exhibits a view of the inside of the eastern wall, with the tube, and machinery by which it is moved. A is the mason-work on the ground; B the universal joint, which allows the tube to turn in all directions; C the speculum in the tube; E the eye-piece through which the observer looks; F a pulley by which the tube is moved; H a chain attached to the pulley, and to the side of the tube; I a chain running to K, the counterpoise; L a lever connecting the chain M with the tube; Z another

139. **Spots on the Sun.**—Spots on the Sun, seem first to have been observed in the year 1611, since which time they have constantly attracted attention, and have been the subject of investigation among astronomers. These spots change their appearance as the Sun revolves on his axis, and become greater or less, to an observer on the Earth, as they are turned to, or from him; they also change in respect to real magnitude and number; one spot, seen by Dr. Herschel, was estimated to be more than six times the size of our Earth, being 50,000 miles in diameter. Sometimes forty or fifty spots may be seen at the same time, and sometimes only one. They are often so large as to be seen with the naked eye; this was the case in 1816.

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MERCURY.

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No signs of an atmosphere have been observed in this planet. The Sun's heat at Mercury is about seven times greater than it is on the Earth, so that water, if nature follows the same laws there that she does here, can not exist at Mercury, except in the state of steam.

The nearness of this planet to the Sun, prevents his being often seen. He may, however, sometimes be observed just before the rising, and a little after the setting of the Sun. When seen after sunset, he appears a brilliant, twinkling star, showing

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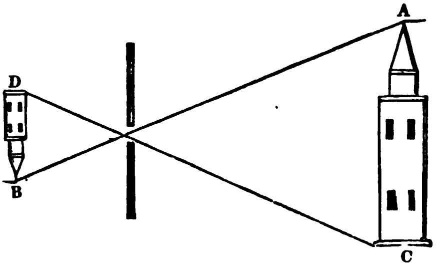
139. When were the spots on the Sun first observed? What has been the difference in the number of spots observed? What was the size of the spots seen by Dr. Herschel? 140. What has been advanced concerning the nature of these spots? Have they been accounted for satisfactorily? 141. What is the diameter of Mercury, and what are his periods of annual and diurnal revolution? How great is the Sun's heat at Mercury? At what times is Mercury to be seen? What is a transit of Mercury?

straight lines, they must cross each other at the point of admission, as explained under the article *Vision.*

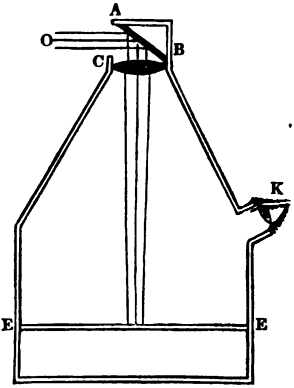
FIG. 225.



Principle of the Camera.

Thus the pencil A, *Fig.* 225, coming from the upper part of the tower, and proceeding straight, will represent the image of that part at B, while the lower part C, for the same reason, will be represented at D. If a convex lens, with a short tube, be placed in the aperture through which the light passes into the room, the images of things will be much more perfect, and their colors more brilliant.

FIG. 226.



Camera Obscura.

This instrument is sometimes employed by painters, in order to obtain an exact delineation of a landscape, an outline of the image being easily taken with a pencil, when the image is thrown on a sheet of paper.

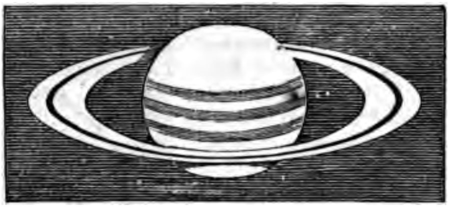
There are several modifications of this machine, and among them the *revolving* camera obscura is the most interesting.

It consists of a small house, *Fig.* 226, with a plane reflector A B, and a double-convex lens C B, placed at its top. The reflector is fixed at an angle of 45 degrees with the horizon, so as to reflect the rays of light perpendicularly downward, and is made to revolve quite around, in either direction, by pulling a string.

Now suppose the small house to be placed in the open air with the mirror, A B, turned toward the east, then the rays of light flowing from the objects in that direction, will strike the mirror in the direction of the lines O, and be reflected down through the convex lens C B, to the table E E, where they will *millions of miles.* His diameter is 79,000 miles, making his bulk nearly nine hundred times greater than that of the Earth, but notwithstanding this vast size, he revolves on his axis once in about ten hours. Saturn, therefore, performs upward of 25,000 diurnal revolutions in one of his years, and hence his year consists of more than 25,000 days; a period of time equal to more than 10,000 of our days. On account of the remote distance of Saturn from the Sun, he receives only about a 90th part of the heat and light which we enjoy on the Earth. But to compensate, in some degree, for this vast distance from the Sun, Saturn has seven moons, which revolve round him at different distances, and at various periods, from 1 to 80 days.

157. *Rings of Saturn.*—Saturn is distinguished from the other planets by his *ring*, as Jupiter is by his belt. When this planet is viewed through a telescope, he appears surrounded by an immense luminous circle, which is represented by *Fig.* 240.

FIG. 240.



Saturn and his Ring.

There are indeed two luminous circles, or rings, one within the other, with a dark space between them, so that they do not appear to touch each other. Neither does the inner ring touch the body of the planet, there being, by estimation, about the distance of thirty thousand miles between them.

The external circumference of the outer ring is 630,000 miles, and its breadth from the outer to the inner circumference, 7,200 miles, or nearly the diameter of our Earth. The dark space, between the two rings, or the interval between the inner and the outer ring, is 2,800 miles.

A third ring, interior to those heretofore known, was discovered in 1851, by Mr. Bond, of Cambridge, Mass.

This immense appendage revolves round the Sun with the planet,—performs daily revolutions with it, and, according to

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157. How is Saturn particularly distinguished from all the other planets? What distance is there between the body of Saturn and his inner ring? What distance is there between his inner and outer ring? What is the circumference of the outer ring?

that its focus can be adjusted to the required distance. Lastly, there is a screen of white cloth, placed at the proper distance, on which the image or shadow of the picture, is seen greatly magnified.

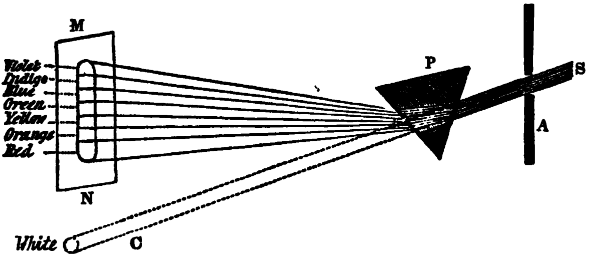
The pictures being of various colors, and so transparent, that the light of the lamp shines through them, the shadows are also of various colors, and thus soldiers and horsemen are represented in their proper costume.

CHROMATICS, OR THE PHILOSOPHY OF COLORS.

94. We have thus far considered light as a simple body, and have supposed that all its parts were equally refracted, in its passage, through the several lenses described. But it will now be shown that light is a compound body, and that each of its rays, which to us appear white, is composed of several colors, and that each color suffers a different degree of refraction, when the rays of light pass through a piece of glass, of a certain shape. This was a discovery of Sir Isaac Newton.

95. Solar Spectrum.—If a ray, proceeding from the sun, be admitted into a darkened chamber, through an aperture in the window shutter, and allowed to pass through a triangular shaped piece of glass, called a *prism*, the light will be decomposed, and instead of a spot of white, there will be seen, on the opposite wall, a most brilliant display of colors, including all those seen in the rainbow.

FIG. 228.



Solar Spectrum.

Suppose S, *Fig.* 228, to be a ray from the sun, admitted through the window shutter A, in such a direction as to fall on

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94. Who made the discovery, that light is a compound substance? 95. In what manner, and by what means, is light decomposed?

THE MOON.

150. The Moon, next to the Sun, is, to us, the most brilliant and interesting of all the celestial bodies. Being the nearest to us of any of the heavenly orbs, and apparently designed for our use, she has been observed with great attention, and many of the phenomena which she presents, are therefore better understood and explained, than those of the other planets.

While the Earth revolves round the sun in a year, it is attended by the Moon, which makes a revolution round the Earth once in 27 days, 7 hours, and 43 minutes. The distance of the Moon from the Earth is 240,000 miles, and her diameter about 2,000 miles.

Her surface, when seen through a telescope, appears diversified with hills, mountains, valleys, rocks, and plains, presenting a most interesting and curious aspect: but the explanation of these phenomena are reserved for another section.

MARS.

151. The next planet in the solar system, is Mars, his orbit surrounding that of the Earth. The diameter of this planet is upward of 4,000 miles, being about half that of the Earth. The revolution of Mars around the Sun is performed in nearly 687 days, or in somewhat less than two of our years, and he turns on his axis once in 24 hours and 40 minutes. His mean distance from the Sun is 144,000,000 of miles, so that he moves in his orbit at the rate of about 55,000 miles in an hour. The days and nights at this planet, and the different seasons of the year, bear a considerable resemblance to those of the Earth. The density of Mars is less than that of the Earth, being only three times that of water.

152. *Telescopic View of Mars.*—This planet, to the naked eye, reflects a yellowish, or dull red light, by which he may be distinguished from all the others. His telescopic appearance is quite peculiar, and often interesting, on account of the changes his face presents, being sometimes spotted, then striped, then clouded, and so on; and sometimes all these figures appear at

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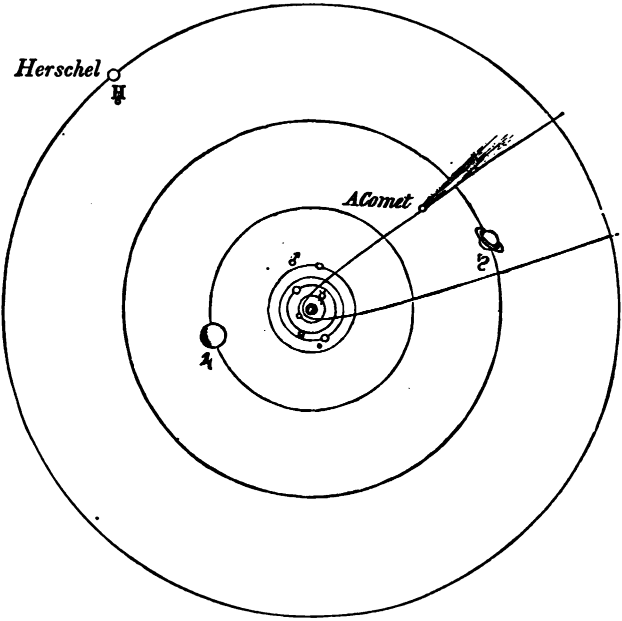
150. Why are the phenomena of the Moon better explained than those of the other planets? In what time is a revolution of the Moon about the Earth performed? What is the distance of the Moon from the Earth? 151. What is the diameter of Mars? How much longer is a year at Mars than our year? What is his rate of motion in his orbit? 152. What is his appearance through the telescope? How is it proved that Mars has an atmosphere of great density? Why does Mars sometimes appear to us larger than at others? How great is the Sun's heat at Mars?

Leverrier, a citizen of France, unknown to each other, pursuing this suggestion, both demonstrated, not only the existence of this undiscovered body, but showed within a few degrees the point in the heavens where it would be found, and where in truth the discovery was made. Dr. Galle, of Berlin, sweeping the heavens with his telescope, according to the directions of these demonstrators, first saw the planet now called Neptune, on the 26th of September, 1846. Still Leverrier and Adams, by the common consent of astronomers and the scientific world, must have the honor of this discovery, "so that the discovery of Neptune, has happily crowned two heads with laurels."

FIG. 242.



Relative Distance of the Planets.

163. This planet was first called *Leverrier*, but it seems that astronomers have long since determined that new ones shall

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163. What is said about calling new planets after their discoverers?

not receive the names of their discoverers, but of some heathen divinity, and hence Herschel, the name of the discoverer, has been changed to Uranus, and Leverrier into Neptune.

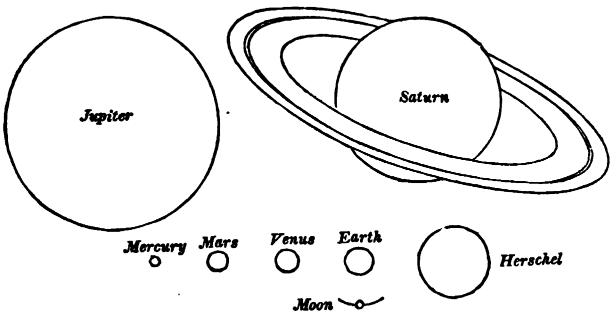
164. *Distance of Neptune.*—It is stated in the table of the planets, that the distance of Neptune from the Sun, is 2,850 millions of millions of miles. On this subject, a curious calculator says, "Had Adam and Eve started on a railway, to go from Neptune to the Sun, at the rate of fifty miles an hour, they would not yet have arrived there, for this planet, at the above rate, is more than 6000 years from the center of our system."

And yet this orb was discovered by the science of man.

RELATIVE SITUATIONS OF THE PLANETS.—Having now given a short account of each planet composing the solar system, the relative situations of their several orbits, with the exception of those of the Asteroids, are shown by *Fig.* 242.

In this figure, the orbits are marked by the signs of each planet, of which the first, or that nearest the Sun, is Mercury, the next Venus, the third the Earth, the fourth Mars; then come those of the Asteroids, then Jupiter, then Saturn, and lastly Herschel.

FIG. 243.



Relative Sizes of the Planets.

COMPARATIVE DIMENSIONS OF THE PLANETS.—The comparative dimensions of the planets are delineated at *Fig.* 243.

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164. How long would it take to go from our system to Neptune, at the rate of fifty miles an hour?

MOTIONS OF THE PLANETS.

It is said, that when Sir Isaac Newton was near demonstrating the great truth, that gravity is the cause which keeps the heavenly bodies in their orbits, he became so agitated with the thoughts of the magnitude and consequences of this discovery, as to be unable to proceed with his demonstrations, and desired a friend to finish what the intensity of his feelings would not allow him to complete.

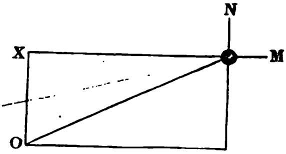
We have seen, in a former part of this work, (183,) that all undisturbed motion is straight forward, and that a body projected into open space, would continue, perpetually, to move in a right line, unless retarded or drawn out of this course by some external cause.

To account for the motions of the planets in their orbits, we will suppose that the Earth, at the time of its creation, was thrown by the hand of the Creator into open space, the Sun having been before created and fixed in his present place.

165. *Circular Motion of the Planets.*—Under *Compound Motion*, (190,) it has been shown, that when a body is acted on by two forces perpendicular to each other, its motion will be in a diagonal between the direction of the two forces.

But we will again here suppose that a ball is moving in the line M X, *Fig.* 244, with a given force, and that another force half as great should strike it in the direction of N, the ball would then describe the diagonal of a parallelogram, whose length would be just equal to twice its breadth, and the line of the ball would be straight, because it would obey the impulse and direction of these two forces only.

FIG. 244.



Diagonal Motion.

Now let A, *Fig.* 245, represent the Earth, and S the Sun; and suppose the Earth to be moving forward, in the line from A to B, and to have arrived at A, with a velocity sufficient, in a given time, and without disturbance, to have carried it to B. But at the point A, the Sun, S, acts upon the Earth with his attractive power, and with a force which would draw it to C,

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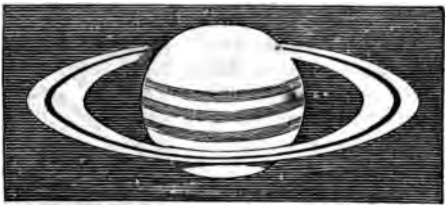
165. Suppose a body to be acted on by two forces perpendicular to each other, in what direction will it move? Why does the ball, Fig. 244, move in a straight line? Why does the Earth, Fig. 245, move in a curved line? Explain Fig. 245, and show how the two forces act to produce a circular line of motion?

millions of miles. His diameter is 79,000 miles, making his bulk nearly nine hundred times greater than that of the Earth, but notwithstanding this vast size, he revolves on his axis once in about ten hours. Saturn, therefore, performs upward of 25,000 diurnal revolutions in one of his years, and hence his year consists of more than 25,000 days; a period of time equal to more than 10,000 of our days. On account of the remote distance of Saturn from the Sun, he receives only about a 90th part of the heat and light which we enjoy on the Earth. But to compensate, in some degree, for this vast distance from the Sun, Saturn has seven moons, which revolve round him at different distances, and at various periods, from 1 to 80 days.

157. *Rings of Saturn.*—Saturn is distinguished from the other planets by his *ring*, as Jupiter is by his belt. When this planet is viewed through a telescope, he appears surrounded by an immense luminous circle, which is represented by *Fig.* 240.

FIG. 240.



Saturn and his Ring.

There are indeed two luminous circles, or rings, one within the other, with a dark space between them, so that they do not appear to touch each other. Neither does the inner ring touch the body of the planet, there being, by estimation, about the distance of thirty thousand miles between them.

The external circumference of the outer ring is 630,000 miles, and its breadth from the outer to the inner circumference, 7,200 miles, or nearly the diameter of our Earth. The dark space, between the two rings, or the interval between the inner and the outer ring, is 2,800 miles.

A third ring, interior to those heretofore known, was discovered in 1851, by Mr. Bond, of Cambridge, Mass.

This immense appendage revolves round the Sun with the planet,—performs daily revolutions with it, and, according to

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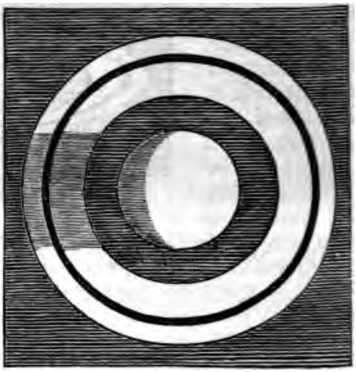
157. How is Saturn particularly distinguished from all the other planets? What distance is there between the body of Saturn and his inner ring? What distance is there between his inner and outer ring? What is the circumference of the outer ring?

Dr. Herschel, is a solid substance, equal in density to the body of the planet itself.

The design of Saturn's ring, an appendage so vast, and so different from any thing presented by the other planets, has always been a matter of speculation and inquiry among astronomers. One of its most obvious uses appears to be that of reflecting the light of the Sun on the body of the planet, and possibly it may reflect the heat also, so as in some degree to soften the rigor of so inhospitable a climate.

158. As this planet revolves around the Sun, one of its sides is illuminated during one half of the year, and the other side during the other half; so that, as Saturn's year is equal to thirty of our years, one of his sides will be enlightened and darkened, alternately, every fifteen years, as the poles of our Earth are alternately in the light and dark every year.

FIG. 241.



Direct View of Saturn.

Fig. 241 represents Saturn as seen by an eye, placed at right-angles to the plane of his ring. When seen from the Earth, his position is always oblique, as represented by *Fig.* 240.

The inner white circle represents the body of the planet, enlightened by the Sun. The dark circle next to this, is the unenlightened space between the body of the planet and the inner ring, being the dark expanse of the heavens beyond the planet. The two white circles are the rings of the planet, with the dark space between them, which also is the dark expanse of the heavens.

The eighth satellite of this planet, was discovered by Mr. Bond, the discoverer of this third ring, as above stated.

HERSCHEL.

159. In consequence of some inequalities in the motions of

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158. How long is one of Saturn's sides alternately in the light and dark? In what position is Saturn represented by Fig. 240?

that thin plates, or minute particles of air, water, and some other substances, reflect certain rays, and absorb or transmit others, and that this is the cause of all their colors.

CHAPTER XII.

ASTRONOMY.

112. This term is compounded of the Greek *astra*, the stars, and *nomos* a law; and hence signifies the laws of the celestial bodies.

Astronomy is that science which treats of the motions and appearance of the heavenly bodies; accounts for the phenomena which these bodies exhibit to us; and explains the laws by which their motions, or apparent motions, are regulated.

Astronomy is divided into *Descriptive*, *Physical*, and *Practical.*

Descriptive astronomy demonstrates the magnitudes, distances, and densities of the heavenly bodies, and explains the phenomena dependent on their motions, such as the change of seasons, and the vicissitudes of day and night.

Physical astronomy explains the theory of planetary motion, and the laws by which this motion is regulated and sustained.

Practical astronomy details the description and use of astronomical instruments, and develops the nature and application of astronomical calculations.

The heavenly bodies are divided into three distinct classes, or systems, namely, *the solar system*, consisting of the sun, moon, and planets; the system of the *fixed stars;* and the system of the *comets.*

THE SOLAR SYSTEM.

113. *The Solar System consists of the Sun, and forty-two other bodies, including the satellites, which revolve around him at various distances, and in various periods of time.*

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112. What is astronomy? How is astronomy divided? What does descriptive astronomy teach? What is the object of physical astronomy? What is practical astronomy? How are the heavenly bodies divided? 113. Of what does the solar system consist?

These bodies, being perpetually in motion, are called *planets*, from a Greek word signifying wanderers, and they are distinguished with reference to their centers of revolution, into *primary* and *secondary*.

114. The *Primary* planets are those which revolve around the sun as their proper center. These are twelve in number; that nearest the sun being Mercury, the others follow in succession, thus: Venus, Earth, Mars, Vesta, Ceres, Pallas, Juno, Jupiter, Saturn, Herschel or Uranus, and Neptune.

115. The *Secondary* planets are those which move round the primaries, as these move round the sun. Of these, there are nineteen, called also *moons*, or *satellites*. These, as we shall see, like their primaries, complete their revolutions at various periods of time.

PRIMARY PLANETS.

116. The following tabular view of the primary planets exhibits their respective diameters; their distances from the sun; the periods of their revolutions round the sun; the periods of their revolutions round their axes, where this is known; and their hourly motion through their several orbits.

Names of the Planets.	Diameter in English miles.	Distances from the Sun in English miles.	Revolution round the Sun.	Periods of revolution on their own axes.			Hourly motion in miles.
			Days.	Days.	Hrs.	M.	
Mercury,	3,221	37.000.000	88	15	0	5	110,000
Venus,	7,687	68.000.000	224¾	0	23	21	80.000
The Earth,	7,912	95.000.000	365¼	1	0	0	68,000
Mars,	4,189	144,000.000	687	1	0	39	55.000
Vesta,	238	225,000,000	1.335	Unknown.			45,000
Ceres,	163	260,000.000	1,681				41,000
Pallas,	80	266.000.000	1.680				41,000
Juno,	1.425	275,000,000	2,008	1	3	0	45,000
Jupiter,	89.170	490.000,000	4.330½	0	9	56	36,000
Saturn.	79,042	900.000,000	10,746¾	0	10	16	22,000
Herschel,	35,112	1.800,000,000	30,637¼	0	7	0	15,000
Neptune,	35,000	2,850,000,000	166 ys.	Unknown.			Unk'wn.

Note. The above table, taken from the last London (Prof. Hoblyn's) edition of our Philosophy, is believed to be correct, according to the most recent observations. It will be seen that in the descriptions of the planets, round numbers are generally employed, as being more easily remembered—also that the periodic revolutions of the planets are given in years, days and hours, instead of days only, as in the table.

117. *A Year, what.*—A year consists of the time which it takes a planet to perform one complete revolution through its

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114. What are the bodies called, which revolve around the Sun as a center? 115 What are those planets called which revolve around these primaries as a center? 116. In what order are the several planets situated in respect to the Sun? How long does it take each planet to make its revolution around the Sun? 117. What is a year?

orbit, or to pass once around the Sun. Our Earth performs this revolution in about 365 days, and therefore this is the period of our year. Mercury completes his revolution in 88 days, and therefore his year is no longer than 88 of our days. But the planet Herschel is situated at such a distance from the Sun, that his revolution is not completed in less than about 84 of our years. The other planets complete their revolutions in various periods of time, between these; so that the time of these periods is generally in proportion to the distance of each planet from the Sun.

118. Besides the above enumerated primary planets, our system contains nineteen secondary planets, or moons. Of these, our Earth has one moon, Jupiter four, Saturn eight, and Herschel six. None of these moons, except our own, and one or two of Saturn's, can be seen without a telescope. The seven other planets, so far as has been discovered, are entirely without moons.

119. All the planets move around the Sun from west to east, and in the same direction do the moons revolve around their primaries, with the exception of those of Herschel, which appear to revolve in a contrary direction.

NEW PLANETS AND ASTEROIDS.

120. The following table contains the names of the new planets and asteroids, with the date, place of discovery, and the name of the discoverer.

Name.	When discovered.	By whom.	Where.
Uranus, . . .	March 13, 1781.	Herschel,	Slough.
Ceres, ...	Jan. 1, 1801.	Piazzi,	Palermo.
Pallas, . . .	March 28, 1802.	Olbers,	Bremen.
Juno, ...	Sept. 1, 1804.	Harding,	Lilienthral.
Vesta, . . .	March 29, 1807.	Olbers,	Bremen.
Astræa, . . .	Dec. 8, 1845.	Hencke,	Driessen.
Neptune, . .	Sept. 23, 1846.	Galle,	Berlin.
Hebe, ...	July 1, 1847.	Hencke,	Driessen.
Iris, ...	Aug. 13, 1847.	Hind,	London.
Flora, ...	Oct. 18, 1847.	Hind,	London.
Metis, . . .	April 25, 1848.	Graham,	Marknee.
Hygeia, . . .	April 12, 1849.	Gasparis,	Naples.
Parthenope, .	May 13, 1850.	Gasparis,	Naples.
Clio, ...	Sept. 13, 1850.	Hind,	London.
Egeria, . . .	Nov. 2, 1850.	Gasparis,	Naples.
Irene, ...	May 20, 1850.	Hind,	London.
New Planet, .	July 29, 1851.	Gasparis,	London.

The preceding table is taken from the American Almanac for 1852.

With the exception of Uranus, or Herschel, and Neptune, these planets are called *Asteroids*, meaning *star-like*, or more recently *Planetoids*, planet-like, on account of their diminutive sizes, and in order to distinguish them from the larger planets.

121. Mr. Hind proposed Victoria, or Clio, for the name of the planet which he discovered on the 13th of September, and at first the name of the Queen was adopted by many foreign astronomers. But it seems that the scientific world have long since refused to name planets after their discoverers, or their patrons, or indeed after any mortal individual, choosing to adopt for them the names of heathen deities, thus following the ancient custom in this respect.

122. *Number of New, or Recently Discovered Celestial Bodies.*—In our former edition, the solar system was stated to consist of the Sun, and twenty-nine bodies revolving around him. At the present time, the number has increased to forty-one, namely, the planet Neptune, and eleven Asteroids, the names and dates of discovery of which, are contained in the preceding table. It has been stated also, that an eighth satellite of Saturn has been discovered, but of this, we have obtained no certain account.

The power and perfection of new astronomical instruments, will probably lead to further celestial discoveries, of which the world at present can have no conception.

123. The following table contains the distances of the Asteroids, or what recently have been called the Planetoids, from the Sun.

The radius of the Earth's orbit, in these computations, is assumed to be 95,000,000 of miles.

Names.	Distances from the Sun in Miles.
1. Flora,	209,160,265
2. Clio,	221,813,220
3. Vesta,	224,302,695
4. Iris,	226,159,280
5. Metis,	226,632,665

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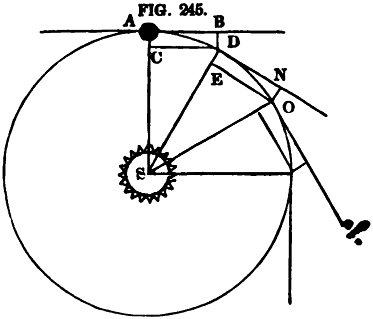
118. How many moons does our system contain? Which of the planets are atended by moons, and how many has each? 119. In what direction do the planets move around the Sun? 121. What is said with respect to the names of the planets? 122. What number of revolving celestial bodies were formerly known? How many have recently been discovered, and what are they called? 123. In the above table what is the estimated distance of the Sun?

FIG. 245.



Circular Motion of the Planets.

in the same space of time that it would otherwise have gone to B. Then the Earth, instead of passing to B, in a straight line, would be drawn down to D, the diagonal of the parallelogram, A B D C. The line of direction, in *Fig.* 244, is straight, because the body moved, obeys only the direction of the two forces, but it is curved from A to D, *Fig.* 245, in consequence of the continued force of the Sun's attraction, which produces a constant deviation from a right line.

When the Earth arrives at D, still retaining its projectile or centrifugal force, its line of direction would be toward N, but while it would pass along to N without disturbance, the attracting force of the Sun is again sufficient to bring it to E, in a straight line, so that, in obedience to the two impulses, it again describes the curve to O.

It must be remembered, in order to account for the circular motions of the planets, that the attractive force of the Sun is not exerted at once, or by a single impulse, as is the case with the cross forces, producing a straight line, but that this force is imparted by degrees, and is constant. It therefore acts equally on the Earth, in all parts of the course from A to D, and from D to O, *Fig.* 245. From O, the Earth having the same impulses as before, it moves in the same curved or circular direction, and thus its motion is continued perpetually.

166. The tendency of the Earth to move forward in a straight line, is called the *centrifugal force*, and the attraction of the Sun, by which it is drawn downward, or toward a center, is called its *centripetal force*, and it is by these two forces that the planets are made to perform their constant revolutions around the Sun, (197.)

167. *Elliptical Orbits.*—In the above explanation, it has been supposed that the Sun's attraction, which constitutes the Earth's gravity, was at all times equal, or that the Earth was at an equal distance from the Sun, in all parts of its orbit.

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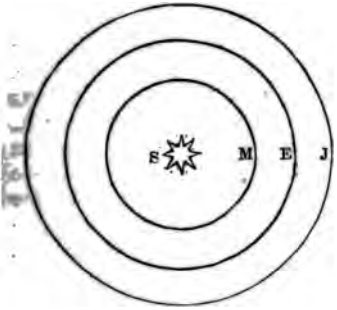
166. What is the projectile force of the Earth called? What is the attractive force of the Sun, which draws the Earth toward him, called?

Earth, and consequently they are called *inferior* planets. The orbits of all the other planets are without, or exterior to that of the Earth, and these are called *superior* planets.

126. That the orbits of Mercury and Venus are within that of the Earth, is evident from the circumstance that they are never seen in opposition to the Sun, that is, they never appear in the west when the Sun is in the east. On the contrary, the orbits of all the other planets are proved to be outside of the Earth's, since these planets are sometimes seen in opposition to the Sun.

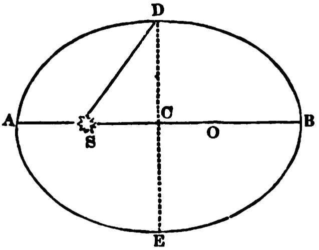
This will be understood by *Fig.* 232, where suppose S to be the Sun, M the orbit of Mercury or Venus, E the orbit of the Earth, and J that of Jupiter. Now, it is evident, that if a spectator be placed any where on the Earth's orbit, as at E, he may sometimes see Jupiter in opposition to the Sun, as at J, because then the spectator would be between Jupiter and the Sun. But the orbit of Venus, being surrounded by that of the Earth, she never can come in opposition to the Sun, or in that part of the heavens opposite to him, as seen by us, because our Earth never passes between her and the Sun.

FIG. 232.



Orbits of the Planets.

FIG. 233.



Elliptical Orbit.

127. *Orbits Elliptical.*—It has already been stated, that the orbits of the planets are elliptical, (124,) and that, consequently, these bodies are sometimes nearer the Sun than at others. An

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126. How is it proved that the inferior planets are within the Earth's orbit, and the superior ones without it? Explain Fig. 232, and show why the inferior planets never can be in opposition to the Sun. 127. What are the shapes of the planetary orbits? What is meant by perihelion? What by aphelion?

169. *Why the Planets do not Fall to the Sun.*—The reason why the planets, when they approach near the Sun, do not fall to him, in consequence of his increased attraction, and why they do not fly off into open space, when they recede to the greatest distance from him, may be thus explained.

Taking the Earth as an example, we have shown that when in the part of her orbit nearest the Sun, her velocity is greatly increased by his attraction, and that consequently the Earth's centrifugal force is increased in proportion.

170. Now, the velocity of the earth increases in an inverse proportion, as its distance from the Sun diminishes, and in proportion to the increase of velocity is its centrifugal force increased; so that, in any other part of its orbit, except when nearest the Sun, this increase of velocity would carry the Earth away from its center of attraction. But this increase of the Earth's velocity is caused by its near approach to the Sun, and consequently the Sun's attraction is increased, as well as the Earth's velocity. In other terms, when the centrifugal force is increased, the centripetal force is increased in proportion, and thus, while the centrifugal force prevents the Earth from falling to the Sun, the centripetal force prevents it from moving off in a straight line.

THE EARTH.

171. *Proofs of the Earth's Diurnal Revolution.*—It is almost universally believed, at the present day, that the apparent daily motion of the heavenly bodies from east to west, is caused by the real motion of the Earth from west to east, and yet there are comparatively few who have examined the evidence on which this belief is founded. For this reason, we will here state the most obvious, and to a common observer, the most convincing proofs of the Earth's revolution. These are, first, the inconceivable velocity of the heavenly bodies, and particularly the fixed stars, around the Earth, if she stands still. Second, the fact that all astronomers of the present age agree, that every phenomenon which the heavens present, can be best accounted for, by supposing the Earth to revolve. Third, the analogy to be drawn from many of the other planets, which are known

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169. How is it shown, that if the motion of a revolving body is increased, its projectile force is also increased? 170. By what force is the Earth's velocity increased as it approaches the Sun? When the Earth is nearest the Sun, why does it not fall to him? When the Earth's centrifugal force is greatest, what prevents its flying from the Sun? 171. What are the most obvious and convincing proofs that the Earth revolves on its axis?

the reach of his rays. The people who live within the arctic circle will, consequently, at this time, enjoy perpetual day.

185. During this period, just the same proportion of the earth that is enlightened in the northern hemisphere, will be in total darkness in the opposite region of the southern hemisphere; so that while the people of the north are blessed with perpetual day, those of the south are groping in perpetual night. Those who live near the arctic circle in the north temperate zone, will, during the Summer, come, for a few hours, within the regions of night, by the Earth's diurnal revolution; and the greater the distance from the circle, the longer will be their nights, and the shorter their days.

186. Hence, at this season, the days will be longer than the nights every where between the equator and the arctic circle. At the equator, the days and nights will be equal, and between the equator and the south polar circle, the nights will be longer than the days, in the same proportion as the days are longer than the nights, from the equator to the arctic circle.

187. *The Sun always Shines on* 180 *Degrees of the Earth.* It will be observed by a careful perusal of the above explanation of the seasons, and a close inspection of the figure by which it is illustrated, that the Sun constantly shines on a portion of the Earth equal to 90 degrees north, and 90 degrees south, from his place in the heavens, and consequently, that he always enlightens 180 degrees, or one half of the Earth. If, therefore, the axis of the Earth were perpendicular to the plane of its orbit, the days and nights would every where be equal, for as the Earth performs its diurnal revolutions, there would be 12 hours day, and 12 hours night. But since the inclination of its axis is 23½ degrees, the light of the Sun is thrown 23½ degrees further in that direction, when the north pole is turned toward the Sun, than it would, had the Earth's axis no inclination. Now, as the Sun's light reaches only 90 degrees north or south of his place in the heavens, so when the arctic circle is enlightened, the antarctic circle must be in the dark; for if the light reaches 23½ degrees beyond the north pole, it must fall 23½ degrees short of the south pole.

188. As the Earth travels round the Sun, in his yearly circuit, this inclination of the poles is alternately toward and from

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185. At what season is the whole antarctic circle in the dark? While the people near the north pole enjoy perpetual day, what is the situation of those near the south pole? 186. At what season will the days be longer than the nights every where between the equator and the arctic circle? 187. How many degrees does the Sun's light reach, north and south of him, on the Earth?

him. During our Winter, the north polar region is thrown beyond the rays of the Sun, while a corresponding portion around the south pole enjoys the Sun's light. And thus, at the poles, there are alternately six months of darkness and Winter, and six months of sunshine and Summer.

189. While we, in the northern hemisphere, are chilled by the cold blasts of Winter, the inhabitants of the southern hemisphere are enjoying all the delights of Summer; and while we are scorched by the rays of a vertical Sun in June and July, our southern neighbors are shivering with the rigors of mid-Winter.

190. At the equator, no such changes take place. The rays of the Sun, as the Earth passes round him, are vertical twice a year at every place between the tropics. Hence, at the equator, there are two Summers and no Winter, and as the Sun there constantly shines on the same half of the Earth in succession, the days and nights are always equal, there being 12 hours of light and 12 of darkness. +

x+ 191. VELOCITY OF THE EARTH.—The motion of the Earth round the Sun, is at the rate of 68,000 miles in an hour, while its motion on its own axis, at the equator, is at the rate of about 1,042 miles in the hour. The equator being that part of the Earth most distant from its axis, the motion there is more rapid than toward the poles, in proportion to its greater distance from the axis of motion.

192. The method of ascertaining the velocity of the Earth's motion, both in its orbit and round its axis, is simple and easily understood; for by knowing the diameter of the Earth's orbit, its circumference is readily found, and as we know how long it takes the Earth to perform her yearly circuit, we have only to calculate what part of her journey she goes through in an hour. By the same principle, the hourly rotation of the Earth is as readily ascertained.

193. We are insensible to these motions, because not only the Earth, but the atmosphere, and all terrestrial things, partake of the same motion, and there is no change in the relation of objects in consequence of it.

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188. During our Winter, is the north pole turned to or from the Sun? At the poles, how many days and nights are there in the year? 189. When it is Winter in the northern hemisphere, what is the season in the southern hemisphere? 190. At what rate does the Earth move around the Sun? What are the seasons at the equator? 191. How fast does it move around its axis at the equator? 192. How is the velocity of the Earth ascertained? 193. Why are we insensible of the Earth's motion?

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CAUSES OF THE HEAT AND COLD OF THE SEASONS.

194. We have seen that the Earth revolves round the Sun in an elliptical orbit, of which the Sun is one of the foci, and consequently that the Earth is nearer him, in one part of her orbit than in another. From the great difference we experience between the heat of Summer and that of Winter, we should be led to suppose that the Earth must be much nearer the Sun in the hot season than in the cold. But when we come to inquire into this subject, and to ascertain the distance of the Sun at different seasons of the year, we find that the great source of heat and light is nearest us during the cold of Winter, and at the greatest distance during the heat of Summer.

195. It has been explained, under the article *Optics*, (39,) that the angle of vision depends on the distance at which a body of given dimensions is seen. Now, on measuring the angular dimensions of the Sun, with accurate instruments, at different seasons of the year, it has been found that his dimensions increase and diminish, and that these variations correspond exactly with the supposition that the Earth moves in an elliptical orbit.

196. If, for instance, his apparent diameter be taken in March, and then again in July, it will be found to have diminished, which diminution is only to be accounted for, by supposing that he is at a greater distance from the observer in July than in March. From July, his angular diameter gradually increases, till January, when it again diminishes, and continues to diminish, until July. By many observations, it is found, that the greatest apparent diameter of the Sun, and therefore his least distance from us, is in January, and his least diameter, and therefore his greatest distance, is in July.

197. The actual difference is about three millions of miles, the Sun being that distance further from the Earth in July than in January. This, however, is only about one-sixtieth of his mean distance from us, and the difference we should experience in his heat, in consequence of this difference of distance, will therefore be very small. Perhaps the effect of his proximity to the Earth may diminish, in some small degree, the severity of Winter.

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194. At what season of the year is the Sun at the greatest, and at what season the least distance from the Earth? 195. How is it ascertained that the Earth moves in an elliptical orbit, by the appearance of the Sun? 196. When does the Sun appear under the greatest apparent diameter, and when under the least? 197. How much further is the Sun from us in July than in January? What effect does this difference produce on the Earth?

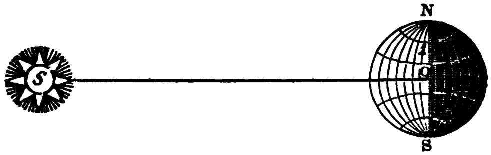
each way, for the poles, take hold of the north pole, and carry it round the circle with the poles constantly parallel to the rod rising above the table. The rod being inclined 23½ degrees from a perpendicular, the poles and axis will be inclined in the same degree, and thus the axis of the earth will be inclined to that of the ecliptic every where in the same degree, and lines drawn in the direction of the Earth's axis will be parallel to each other in any part of its orbit.

179. This will be understood by *Fig.* 247, where it will be seen, that the poles of the Earth, in the several positions of A B C and D, being equally inclined, are parallel to each other. Supposing the lamp to represent the Sun, and the wire circle the Earth's orbit, the actual position of the Earth, during its annual revolution around the Sun, will be comprehended, and if the globe be turned on its axis, while passing round the lamp, the diurnal, or daily revolutions of the Earth will also be represented.

DAY AND NIGHT.

180. *Were the direction of the Earth's axis perpendicular to the plane of its orbit, the days and nights would be of equal length all the year, for then just one half of the Earth, from pole to pole, would be enlightened, and at the same time the other half would be in darkness.*

FIG. 248.



Day and Night.

Suppose the line S *o*, *Fig.* 248, from the Sun to the Earth, to be the plane of the Earth's orbit, and that N S is the axis of the Earth perpendicular to it, then it is obvious, that exactly

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179. How does it appear by Fig. 247, that the axis of the Earth is parallel to itself, n all parts of its orbit? 180. How are the annual and diurnal revolutions of the Earth illustrated by Fig. 248? Explain, by Fig. 248, why the days and nights would very where be equal, were the axis of the Earth perpendicular to the plane of his orbit.

tion, and that only half the heat would be imparted. This is the effect produced by the Sun's rays in the Winter. They fall so obliquely on the Earth, as to occupy nearly double the space that the same number of rays do in the Summer.

This is illustrated by *Fig.* 250, where the number of rays, both in Winter and Summer, are supposed to be the same. But, it will be observed, that the Winter rays, owing to their oblique direction, are spread over nearly twice as much surface as those of Summer.

202. It may, however, be remarked, that the hottest season is not usually at the exact time of the year, when the Sun is most vertical, and the days the longest, as is the case toward the end of June, but some time afterward, as in July and August.

203. To account for this, it must be remembered, that when the Sun is nearly vertical, the Earth accumulates more heat by day than it gives out at night, and that this accumulation continues to increase after the days begin to shorten, and, consequently, the greatest elevation of temperature is some time after the longest days. For the same reason, the thermometer generally indicates the greatest degree of heat at two or three o'clock on each day, and not at twelve o'clock, when the Sun's rays are most powerful.

FIGURE OF THE EARTH.

204. Astronomers have proved that all the planets, together with their satellites, have the shape of the sphere, or globe, and hence, by analogy, there was every reason to suppose that the Earth would be found of the same shape; and several phenomena tend to prove, beyond all doubt, that this is its form. The figure of the Earth is not, however, exactly that of a globe, or ball, because its diameter is about 34 miles less from pole to pole, than it is at the equator. But that its general figure is that of a sphere, or ball, is proved by many circumstances.

205. When one is at sea, or standing on the sea-shore, the first part of a ship seen at a distance, is its mast. As the vessel advances, the mast rises higher and higher above the horizon, and finally the hull, and whole ship, become visible. Now, were the Earth's surface an exact plane, no such appearance

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201. How is the actual difference of the Summer and Winter rays shown? 202. Why is not the hottest season of the year at the period when the days are longest, and the Sun most vertical? 203. How is this accounted for? 204. What is the general figure of the Earth? How much less is the diameter of the Earth at the poles than at the equator? 205. How is the convexity of the Earth proved, by the approach of a ship at sea? Explain Fig. 251.

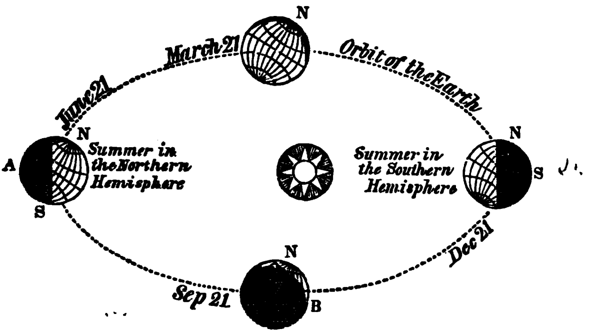
other. The Earth, in its yearly revolution, passes through each of these points. One is called the *Summer*, and the other the *Winter* solstice. The Sun is said to enter the Summer solstice on the 21st of June and at this time, in our hemisphere, the days are longest and the nights shortest. On the 21st of December, he enters his Winter solstice, when the length of the days and nights are reversed from what they were in June before, the days being shortest, and the nights longest.

Having learned these explanations, the student will be able to understand in what order the seasons succeed each other, and the reason why such changes are the effect of the Earth's revolution.

REVOLUTIONS OF THE EARTH.

184. Suppose the Earth, *Fig.* 249, to be in her Summer solstice, which takes place on the 21st of June. At this period she will be at A, having her north pole, N so inclined toward the Sun, that the whole arctic circle will be illuminated, and consequently the Sun's rays will extend 23½ degrees, the breadth of the polar circle, beyond the north pole. The diurnal revolution, therefore, when the Earth is at A, causes no succession of day and night at the pole, since the whole frigid zone is within

FIG. 249.


N
March 21
Orbit of the Earth
June 21
N
Summer in the Northern Hemisphere
A
S
N
Summer in the Southern Hemisphere
S
Dec 21
N
Sep 21
B

Seasons of the Year.

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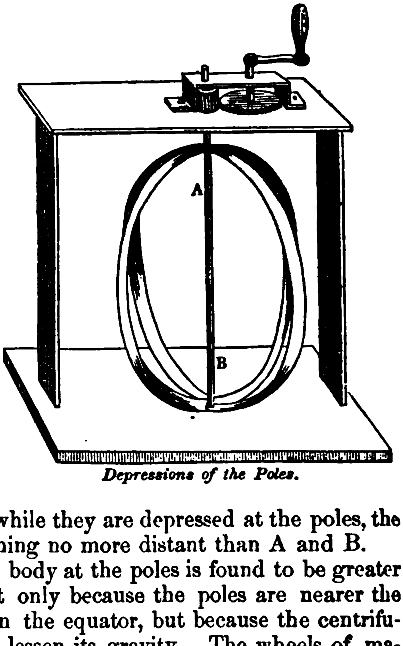
184. At what season of the year is the whole arctic circle illuminated ?

rapidly, by means of a stick passing through its center, as an axis, it will swell out in the middle, or equator, and be depressed at the poles, assuming the precise figure of the Earth.

208. *Centrifugal Force.*—The effects of centrifugal force are very satisfactorily illustrated in the following manner:—

Two hoops of thin iron are placed upon an axis which passes through their poles, as shown by *Fig.* 252. The two poles of each hoop cross each other at right-angles, and are fastened together, and to the axis at the bottom. At the upper end they slide up and down on the axis, which is turned rapidly by wheel-work as represented. These hoops, before the motion begins, have an oval form, but when turned rapidly, the centrifugal force occasions them to expand, or swell at the equator, while they are depressed at the poles, the two polar regions becoming no more distant than A and B.

FIG. 252.



Depressions of the Poles.

209. The weight of a body at the poles is found to be greater than at the equator, not only because the poles are nearer the center of the Earth than the equator, but because the centrifugal force there tends to lessen its gravity. The wheels of machines, which revolve with the greatest rapidity, are made in the strongest manner, otherwise they will fly in pieces, the centrifugal force not only overcoming the gravity, but the cohesion of their parts.

210. It has been found, by calculation, that if the Earth turned over once in 84 minutes and 43 seconds, the centrifugal

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208. Explain Fig. 252, and show how it illustrates the form of the earth. 209. What two causes render the weights of bodies less at the equator than at the poles? 210. What would be the consequence on the weights of bodies at the equator, did the Earth turn over once in 84 minutes and 43 seconds?

him. During our Winter, the north polar region is thrown beyond the rays of the Sun, while a corresponding portion around the south pole enjoys the Sun's light. And thus, at the poles, there are alternately six months of darkness and Winter, and six months of sunshine and Summer.

189. While we, in the northern hemisphere, are chilled by the cold blasts of Winter, the inhabitants of the southern hemisphere are enjoying all the delights of Summer; and while we are scorched by the rays of a vertical Sun in June and July, our southern neighbors are shivering with the rigors of mid-Winter.

190. At the equator, no such changes take place. The rays of the Sun, as the Earth passes round him, are vertical twice a year at every place between the tropics. Hence, at the equator, there are two Summers and no Winter, and as the Sun there constantly shines on the same half of the Earth in succession, the days and nights are always equal, there being 12 hours of light and 12 of darkness.

191. Velocity of the Earth.—The motion of the Earth round the Sun, is at the rate of 68,000 miles in an hour, while its motion on its own axis, at the equator, is at the rate of about 1,042 miles in the hour. The equator being that part of the Earth most distant from its axis, the motion there is more rapid than toward the poles, in proportion to its greater distance from the axis of motion.

192. The method of ascertaining the velocity of the Earth's motion, both in its orbit and round its axis, is simple and easily understood; for by knowing the diameter of the Earth's orbit, its circumference is readily found, and as we know how long it takes the Earth to perform her yearly circuit, we have only to calculate what part of her journey she goes through in an hour. By the same principle, the hourly rotation of the Earth is as readily ascertained.

193. We are insensible to these motions, because not only the Earth, but the atmosphere, and all terrestrial things, partake of the same motion, and there is no change in the relation of objects in consequence of it.

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188. During our Winter, is the north pole turned to or from the Sun? At the poles, how many days and nights are there in the year? 189. When it is Winter in the northern hemisphere, what is the season in the southern hemisphere? 190. At what rate does the Earth move around the Sun? What are the seasons at the equator? 191. How fast does it move around its axis at the equator? 192. How is the velocity of the Earth ascertained? 193. Why are we insensible of the Earth's motion?

a day happens to a traveler, who, in passing round the Earth to the west, reckons his time by the rising and setting of the Sun. If he passes round toward the east, he will gain a day for the same reason.

EQUATION OF TIME.

214. As the motion of the Earth about its axis is perfectly uniform, the siderial days are exactly of the same length, in all parts of the year. But as the orbit of the Earth, or the apparent path of the Sun, is inclined to the Earth's axis, and as the Earth moves with different velocities in different parts of its orbit, the solar, or natural days, are sometimes greater and sometimes less than 24 hours, as shown by an accurate clock. The consequence is, that a true sun-dial, or noon mark, and a true time-piece, agree with each other only a few times in a year. The difference between the sun-dial and clock, thus shown, is called the *equation of time.*

215. The difference between the Sun and a well regulated clock, thus arises from two causes, the inclination of the Earth's axis to the ecliptic, and the elliptical form of the Earth's orbit.

That the Earth moves in an ellipse, and that its motion is more rapid sometimes than at others, as well as that the Earth's axis is inclined to the ecliptic, have already been explained and illustrated. It remains, therefore, to show how these two combined causes, the elliptical form of the orbit, and the inclination of the axis, produce the disagreement between the Sun and clock.

MEAN TIME.

216. *Equal,* or *mean* time, is that which is reckoned by a clock, supposed to indicate exactly 24 hours, from 12 o'clock on one day, to 12 o'clock on the next day. *Apparent* time, is that which is measured by the apparent motion of the Sun in the heavens, as indicated by a meridian line, or sun-dial.

217. Were the Earth's orbit a perfect circle, and her axis perpendicular to the plane of this orbit, the days would be of a uniform length, and there would be no difference between the clock and the Sun; both would indicate 12 o'clock at the same

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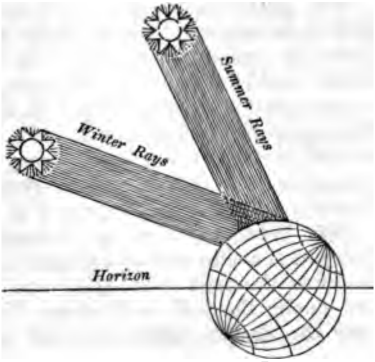
214. Why are the solar days sometimes greater, and sometimes less, than 24 hours? What is the difference between the time of a sun-dial and clock called? 215. What are the causes of the difference between the Sun and clock. 216. What is meant by equal, or mean time? 217. Were the Earth's orbit a perfect circle, and her axis perpendicular to its plane, what would be the effect on time?

198. *Temperature of Summer and Winter.*—The heat of Summer, and the cold of Winter, must therefore arise from the difference in the meridian altitude of the Sun, and in the time of his continuance above the horizon. In Summer, the solar rays fall on the Earth, in nearly a perpendicular direction, and his powerful heat is then constantly accumulated by the long days and short nights of the season.

199. In Winter, on the contrary, the solar rays fall so obliquely on the Earth, as to produce little warmth, and the small effect they do produce during the short days of that season, is almost entirely destroyed by the long nights which succeed. The difference between the effects of perpendicular and oblique rays, seems to depend, in a great measure, on the different extent of surface over which they are spread.

200. When the rays of the Sun are made to pass through a convex lens, the heat is increased, because the number of rays which naturally cover a large surface, are then made to cover a smaller one, so that the power of the glass depends on the number of rays thus brought to a focus. If, on the contrary, the rays of the Sun are suffered to pass through a concave lens, their natural heating power is diminished, because they are dispersed, or spread over a wider surface than before.

FIG. 250.



Summer and Winter Rays.

201. *Summer and Winter Rays.*—Now to apply these different effects to the Summer and Winter rays of the Sun, let us suppose that the rays falling perpendicularly on a given extent of surface, impart to it a certain degree of heat, then it is obvious, that if the same number of rays be spread over twice that extent of surface, their heating power would be diminished in propor-

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198. How is the heat of Summer, and the cold of Winter, accounted for? Why do the perpendicular rays of Summer produce greater effects than the o rays of Winter? 200. How is this illustrated by the convex and concave lens

during that time, which is more than the twelfth part of her orbit, there being more than twelve lunar periods in the year.

222. *Illustration by the Hands of a Watch.*—These two revolutions may be familiarly illustrated by the motions of the hour and minute hands of a watch. Let us suppose the 12 hours marked on the dial plate of a watch to represent the 12 signs of the zodiac through which the Sun seems to pass in his yearly revolution, while the hour hand of the watch represents the Sun, and the minute hand the Moon. Then, as the hour hand goes around the dial plate once in 12 hours, so the Sun apparently goes around the zodiac once in twelve months; and as the minute hand makes 12 revolutions to one of the hour hand, so the Moon makes 12 revolutions to one of the Sun. But the Moon, or minute hand, must go more than once round, from any point on the circle, where it last came in conjunction with the Sun, or hour hand, to overtake it again, since the hour hand will have moved forward of the place where it was last overtaken, and consequently the next conjunction must be forward of the place where the last happened. During an hour, the hour hand describes the twelfth part of the circle, but the minute hand has not only to go round the whole circle in an hour, but also such a portion of it as the hour hand has moved forward since they last met. Thus, at 12 o'clock, the hands are in conjunction; the next conjunction is 5 minutes 27 seconds past I o'clock; the next, 10 min. 54 sec. past II o'clock; the third, 16 min. 21 sec. past III; the 4th, 21 min. 49 sec. past IV; the 5th, 27 min. 10 sec. past V; the 6th, 32 min. 43 sec. past VI; the 7th, 38 min. 10 sec. past VII; the 8th, 43 min. 38 sec. past VIII; the 9th, 49 min. 5 sec. past IX; the 10th, 54 min. 32 sec. past X; and the next conjunction is at XII.

223. The same principle is true in respect to the Moon; for as the Earth advances in its orbit, it takes the Moon 2 days, 5 hours and 1 minute longer to come again in conjunction with the Sun, than it does to make her monthly revolution round the Earth; and this 2 days 5 hours and 1 minute being added to 27 days 7 hours and 43 minutes, the time of the periodical revolution, makes 29 days 12 hours and 44 minutes, the period of her synodical revolution.

224. *We only see one Side of the Moon.*—The Moon always

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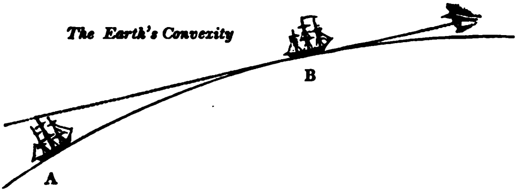
222. How are these two revolutions of the Moon illustrated by the two hands of a watch? Mention the time of several conjunctions between the two hands of a watch. 223. How much longer does it take the Moon to come again in conjunction with the Sun, than it does to perform her periodical revolution? 224. How is it proved that the Moon makes but one revolution on her axis, as she passes around the Earth?

FIG. 251.



Spheroidal Form of the Earth.

would take place, for we should then see the hull long before the mast or rigging, because it is much the largest object.

It will be plain by *Fig.* 251, that were the ship, A, elevated so that the hull should be on a horizontal line with the eye, the whole ship would be visible, instead of the topmast, there being no reason, except the convexity of the earth, why the whole ship should not be visible at A, as well as at B.

206. We know, for the same reason, that in passing over a hill, the tops of the trees are seen, before we can discover the ground on which they stand; and that when a man approaches from the opposite side of a hill, his head is seen before his feet.

It is a well known fact also, that navigators have set out from a particular port, and by sailing continually westward, have passed around the Earth, and again reached the port from which they sailed. This could never happen, were the Earth an extended plain, since then the longer the navigator sailed in one direction, the further he would be from home.

Another proof of the spheroidal form of the Earth, is the figure of its shadow on the Moon, during eclipses, which shadow is always bounded by a circular line.

These circumstances prove beyond all doubt, that the form of the Earth is globular, but that it is not an exact sphere; and that it is depressed or flattened at the poles, is shown by the difference in the lengths of pendulums vibrating seconds at the poles, and at the equator.

207. The compression of the Earth at the poles, and the consequent accumulation of matter at the equator, is considered the effect of its diurnal revolution, while it was in a soft or plastic state. If a ball of soft clay, or putty, be made to revolve

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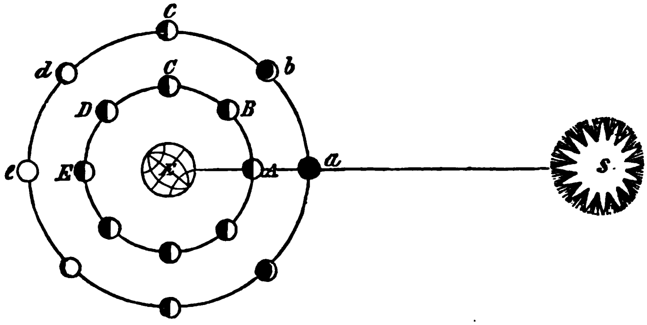
206. What other proofs of the globular shape of the Earth are mentioned? 207. How is the form of the Earth illustrated by experiment? Explain the reason why a plastic ball will swell at the equator, when made to revolve.

FIG. 253.



Phases of the Moon.

sented at *a*. The Sun always shines on one half of the Moon, in every direction, as represented at A and B, on the inner circle; but we at the Earth can see only such portions of the enlightened part as are turned toward us. After her change, when she has moved from A to B, a small part of her illuminated side comes in sight, and she appears horned, as at *b*, and is then called the *new* Moon. When she arrives at C, several days afterward, one half of her disc is visible, and she appears as at *c*, her appearance being the same in both circles. At this point she is said to be in her *first quarter*, because she has passed through a quarter of her orbit, and is 90 degrees from the place of her conjunction with the Sun. At D, she shows us still more of her enlightened side, and is then said to appear *gibbous*, as at *d*. When she comes to F, her whole enlightened side is turned toward the Earth, and she appears in all the splendor of the *full* Moon. During the other half of her revolution she daily shows less and less of her illuminated side, until she again becomes invisible by her conjunction with the Sun. Thus in passing from her conjunction *a*, to her full *e*, the Moon appears every day to increase, while in going from her full to her conjunction again, she appears to us constantly to decrease, but as seen from the Sun, she appears always full.

229. *How the Earth appears at the Moon.*—The earth, seen by the inhabitants of the Moon, exhibits the same phases that

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229. What is said concerning the phases of the Earth, as seen from the Moon? When does the Earth appear full at the Moon?

force at the equator would be equal to the power of gravity there, and that bodies would entirely lose their weight. If the Earth revolved more rapidly than this, all the buildings, rocks, mountains, and men, at the equator, would not only lose their weight, but would fly away, and leave the Earth, as the water does from a revolving grindstone.

SOLAR AND SIDERIAL TIME.

211. The stars appear to go round the Earth in 23 hours, 56 minutes, and 4 seconds, while the Sun appears to perform the same revolution in 24 hours, so that the stars gain 3 minutes and 56 seconds upon the Sun every day. In a year, this amounts to a day, or to the time taken by the Earth to perform one diurnal revolution. It therefore happens, that when time is measured by the stars, there are 366 days in the year, or 366 diurnal revolutions of the Earth; while, if measured by the Sun from one meridian to another, there are only 365 whole days in the year. The former are called the *siderial*, and the latter *solar* days.

212. If the Earth had only a diurnal motion, her revolution, in respect to the Sun, would coincide exactly with the same revolution in respect to the stars; but while she is making one revolution on her axis toward the east, she advances in the same direction about one degree in her orbit, so that to bring the same meridian toward the Sun, she must make a little more than one entire revolution.

213. Thus, the Earth must complete one revolution, and a portion of a second revolution, equal to the space she has advanced in her orbit, in order to bring the same meridian back again to the Sun. This small portion of a second revolution amounts daily to the 365th part of her circumference, and therefore, at the end of the year, to one entire rotation, and hence, in 365 days, the Earth actually turns on her axis 366 times. Thus, as one complete rotation forms a siderial day, there must, in the year, be one siderial, more than there are solar days, one rotation of the Earth, with respect to the Sun, being lost, by the Earth's yearly revolution. The same loss of

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211. The stars appear to move round the Earth in less time than the Sun; what does the difference amount to in a year? What is the year measured by a star called? What is that measured by the Sun called? 212. Had the Earth only a diurnal revolution, would the siderial and solar time agree? 213. How many times does the Earth turn on her axis in a year? Why does she turn more times than there are days in the year?

rection opposite to him, just as the shadow of a man reaches from the Sun.

235. *Eclipses, what.*—Eclipses are of two kinds, namely *Lunar*, an eclipse of the Moon, and *Solar*, an eclipse of the Sun. The first is occasioned by the shadow of the Earth on the Moon, and the second by the shadow of the Moon on the Earth.

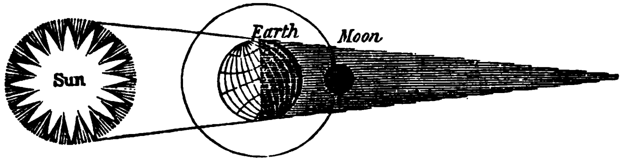
Hence, in both cases, the two planets and the Sun must be in nearly a straight line with respect to each other. In eclipses of the Moon, the Earth is between the Sun and Moon; and in eclipses of the Sun, the Moon is between the Earth and Sun.

LUNAR ECLIPSES.

236. *When the Moon falls into the shadow of the Earth, the rays of the Sun are intercepted, or hid from her, and she then becomes eclipsed.*

When the Earth's shadow covers only a part of her face, as seen by us, she suffers only a *partial* eclipse, one part of her disc being obscured, while the other part reflects the Sun's light. But when her whole surface is obscured by the Earth's shadow, she then suffers a *total* eclipse, and of a duration proportionate to the distance she passes through the Earth's shadow.

FIG. 254.



Eclipse of the Moon.

237. *Fig.* 254 represents a total lunar eclipse; the Moon being in the midst of the Earth's shadow. Now it will be apparent that in the situation of the Sun, Earth, and Moon. as represented in the figure, this eclipse will be visible from all parts of that hemisphere of the Earth which is next the Moon, and that the Moon's disc will be equally obscured, from whatever point it is seen. When the moon passes through only a

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235. What occasions the lunar, and what the solar eclipse? 236. What is meant by a partial, and what by a total eclipse? 237. Why is the same eclipse total at one place, and only partial at another?

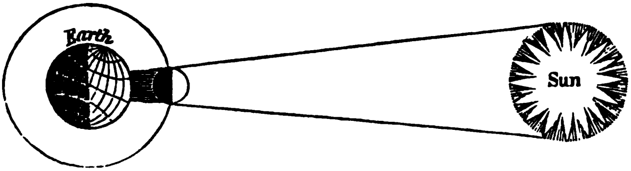
part of the Earth's shadow, then she suffers only a partial eclipse, but this is also visible from the whole hemisphere next the Moon. It will be remembered that lunar eclipses happen only at full Moon, the Sun and Moon being in opposition, and the Earth between them.

SOLAR ECLIPSES.

238. *When the Moon passes between the Earth and Sun, there happens an eclipse of the Sun, because then the Moon's shadow falls upon the Earth.*

239. A total eclipse of the Sun happens often, but when it occurs, the total obscurity is confined to a small part of the Earth; since the dark portion of the Moon's shadow never exceeds 200 miles in diameter on the Earth. But the Moon's partial shadow, or *penumbra*, may cover a space on the Earth of more than 4,000 miles in diameter, within all which space the Sun will be more or less eclipsed. When the penumbra first touches the Earth, the eclipse begins at that place, and ends when the penumbra leaves it. But the eclipse will be total only where the dark shadow of the Moon touches the Earth.

FIG. 255.



Eclipse of the Sun.

Fig. 255, represents an eclipse of the Sun, without regard to the penumbra, that it may be observed how small a part of the Earth the dark shadow of the Moon covers. To those who live within the limits of this shadow, the eclipse will be total, while to those who live in any direction around it, and within reach of the penumbra, it will be only partial.

240. Solar eclipses are called *annular*, from *annulus*, a ring,

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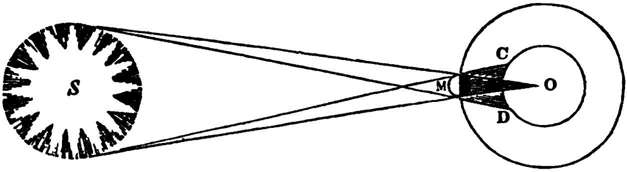
238. Why is a total eclipse of the Sun confined to so small a part of the Earth? 239. What is meant by penumbra? What will be the difference in the aspect of the eclipse, whether the observer stands within the dark shadow, or only within the penumbra? 240. What is meant by annular eclipses? Are annular eclipses ever total in any part of the Earth? In annular eclipses, what part of the Moon's shadow reaches the Earth?

when the Moon passes across the center of the Sun, hiding all his light, with the exception of a ring on his outer edge, which the Moon is too small to cover from the position in which it is seen.

241. *Umbra and Penumbra.*—A solar eclipse, with the *penumbra*, or light and shadow, D C, and the *umbra*, or dark shadow, O, is seen in *Fig.* 256.

When the Moon is at its greatest distance from the Earth, its shadow M O, sometimes terminates before it reaches the Earth, and then an observer standing directly under the point O, will see the outer edge of the Sun, forming a bright ring around the circumference of the Moon, thus forming an *annular* eclipse.

FIG. 256.



Umbra and Penumbra.

The penumbra D C, is only a partial interception of the Sun's rays, and in annular eclipses it is this partial shadow only which reaches the Earth, while the umbra, or dark shadow, terminates in the air. Hence annular eclipses are never total in any part of the Earth. The penumbra, as already stated, may cover more than 4,000 miles of space, while the umbra never covers more than 200 miles in diameter; hence partial eclipses of the Sun may be seen by a vast number of inhabitants, while comparatively few will witness the total eclipse.

242. When there happens a total solar eclipse to us, we are eclipsed to the Moon, and when the Moon is eclipsed to us, an eclipse of the Sun happens to the Moon. To the Moon, an eclipse of the Earth can never be total, since her shadow covers only a small portion of the Earth's surface. Such an eclipse, therefore, at the Moon, appears only as a dark spot on the face of the Earth; but when the Moon is eclipsed to us, the Sun is partially eclipsed to the Moon for several hours longer than the Moon is eclipsed to us.

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241. What do penumbra, and umbra, mean? 242. What is said concerning eclipses of the Earth, as seen from the Moon?

presents the same side, or face, toward the Earth, and hence it is evident that she turns on her axis but once, while she is performing one revolution round the Earth, so that the inhabitants of the Moon have but one day and night in the course of a lunar month.

225. One half of the Moon is never in the dark, because when this half is not enlightened by the Sun, a strong light is reflected to her from the Earth, during the Sun's absence. The other half of the Moon enjoys alternately two weeks of the Sun's light, and two weeks of total darkness.

PHASES OF THE MOON.—One of the most interesting circumstances to us, respecting the Moon, is the constant changes which she undergoes, in her passage around the Earth. When she first appears, a day or two after her change, we can see only a small portion of her enlightened side, which is in the form of a crescent; and at this time she is commonly called new Moon. From this period she goes on increasing, or showing more and more of her face, every evening, until at last she becomes round, and her face is fully illuminated. She then begins again to decrease, by apparently losing a small section of her face, and the next evening another small section from the same part, and so on, decreasing a little every day, until she entirely disappears; and having been absent a day or two, reappears in the form of a crescent, or new Moon, as before.

226. When the Moon disappears, she is said to be in *conjunction*, that is, she is in the same direction from us with the Sun. When she is full, she is said to be in *opposition*, that is, she is in that part of the heavens opposite to the Sun, as seen by us.

227. The different appearances of the Moon from *new* to *full*, and from *full* to *change*, are owing to her presenting different portions of her enlightened surface toward us at different times. These appearances are called *phases* of the Moon, and are easily accounted for, and understood by the following figure.

228. Let S, *Fig.* 253, be the Sun, E the Earth, and A, B, C, D, F, the Moon in different parts of her orbit. Now when the Moon changes, or is in conjunction with the Sun, as at A, her dark side is turned toward the Earth, and she is invisible, as repre-

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225. One half of the Moon is never in the dark; explain why this is so. How long is the day and night at the other half? How is it shown that the Moon shines only by reflected light? 226. When is the Moon said to be in conjunction with the Sun, and when in opposition to the Sun? 227. What are the phases of the Moon? 228 Describe Fig. 253, and show how the Moon passes from change to full, and from full to change.

Moon's attraction would raise the tides only as she passed round the Earth. But as the Earth turns on her axis every 24 hours, and as the waters nearest the Moon, as at A, are constantly elevated, they will, in the course of 24 hours, move round the whole Earth, and consequently from this cause there will be high water at every place once in 24 hours. As the elevation of the waters under the Moon causes their depression at 90 degress distance on the opposite sides of the Earth, D and C, the point C will come to the same place, by the Earth's diurnal revolution, six hours after the point A, because C is one quarter of the circumference of the Earth from the point A, and therefore, there will be low water at any given place six hours after it was high water at that place.

248. But while it is high water under the Moon, in consequence of her direct attraction, it is also high water on the opposite side of the Earth in consequence of her diminished attraction, and the Earth's centrifugal motion, and therefore it will be high water from this cause twelve hours after it was high water from the former cause, and six hours after it was low water from both causes.

249. But while the Earth turns on her axis, the Moon advances in her orbit, and consequently any given point on the Earth will not come under the Moon on one day so soon as it did on the day before. For this reason, high or low water at any place comes about fifty minutes later on one day than it did the day before.

Thus far we have considered no other attractive influence except that of the Moon, as affecting the waters of the ocean. But the Sun, as already observed, has an effect upon the tides, though on account of his great distance, his influence is small when compared with that of the Moon.

250. When the Sun and Moon are in conjunction, as represented in *Fig.* 257, which takes place at her change, or when they are in opposition, which takes place at full Moon, then their forces are united, or act on the waters in the same direction, and consequently the tides are elevated higher than usual, and on this account are called *spring tides.*

251. *Neap Tides.*—But when the Moon is in her quadratures, or quarters, the attraction of the Sun tends to counteract

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248. When it is high water under the Moon by her attraction, what is the cause of high water on the opposite side of the Earth, at the same time? 249. Why are the tides about fifty minutes later every day? 250. What produces spring tides? Where must the Moon be in respect to the Sun, to produce spring tides? 251 What is the occasion of neap tides?

the Moon does to us, but in a contrary order. When the Moon is in her conjunction, and consequently invisible to us, the Earth appears full to the people of the Moon, and when the Moon is full to us, the Earth is dark to them.

230. *The Earth shines upon the Moon.*—That the Earth shines upon the Moon, as the Moon does upon us, is proved by the fact that the outline of her disc may be seen, when only a part of it is enlightened by the Sun. Thus when the sky is clear, and the Moon only two or three days old, it is not uncommon to see the brilliant new Moon, with her horns enlightened by the Sun, and at the same time the old Moon faintly illuminated by reflection from the Earth. This phenomenon is sometimes called "the old Moon in the new Moon's arms."

231. It was a disputed point among former astronomers, whether the Moon has an atmosphere; but the more recent discoveries have decided that she has an atmosphere, though there is reason to believe that it is much less dense than ours.

232. *Surface of the Moon.*—When the Moon's surface is examined through a telescope, it is found to be wonderfully diversified, for besides the dark spots perceptible to the naked eye, there are seen extensive valleys, and long ridges of highly elevated mountains.

Some of these mountains, according to Dr. Herschel, are 4 miles high, while hollows more than three miles deep, and almost exactly circular, appear excavated on the plains. Astronomers have been at vast labor to enumerate, figure, and describe the mountains and spots on the surface of the Moon, so that the latitude and longitude of about 100 spots have been ascertained, and their names, shapes, and relative positions given. A still greater number of mountains have been named, and their heights and the lengths of their bases detailed.

233. The deep caverns, and broken appearance of the Moon's surface, long since induced astronomers to believe that such effects were produced by volcanoes, and more recent discoveries have seemed to prove that this suggestion was not without foundation.

ECLIPSES.

234. *Every planet and satellite in the Solar System, is illuminated by the Sun, and hence they cast shadows in the di-*

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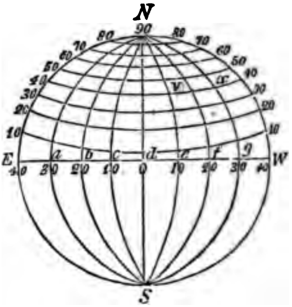
230. How is it known that the Earth shines upon the Moon, as the Moon does upon us? 231. What is said concerning the Moon's atmosphere? 232. How high are some of the mountains, and how deep the caverns of the Moon? 233. What is said concerning the volcanoes of the Moon? 234. What is a lunar, and what a solar eclipse?

cause every such place must be at the same distance from the equator. The length of a degree of latitude is 60 geographical miles.

253. *Longitude is the distance measured in degrees and minutes, either east or west, from any given point on the equator, or on any parallel of latitude.* Hence the lines, or meridians of longitude, cross those of latitude at right-angles. The degrees of longitude are 180 in number, its lines extending half a circle to the east, and half a circle to the west, from any given meridian, so as to include the whole circumference of the Earth. A degree of longitude, at the equator, is of the same length as a degree of latitude, but as the poles are approached, the degrees of longitude diminish in length, because the Earth grows smaller in circumference from the equator toward the poles; hence the lines surrounding it become less and less. This will be made obvious by *Fig.* 259.

FIG. 259.



Parallels of Longitude.

Let this figure represent the Earth, N being the north pole, S the south pole, and E W the equator. The lines 10, 20, 30, and so on, are the parallels of latitude, and the lines N *a* S, N *b* S, &c., are meridian lines, or those of longitude.

The latitude of any place on the globe, is the number of degrees between that place and the equator, measured on a meridian line; thus, *x* is in latitude 40 degrees, because the *x g* part of the meridian contains 40 degrees. The longitude of a place is the number of degrees it is situated east or west from any meridian line; thus, *v* is 20 degrees west longitude from *x*, and *x* is 20 degrees east longitude from *v*.

254. As the equator divides the Earth into two equal parts, or hemispheres, there seems to be a natural reason why the degrees of latitude should be reckoned from this great circle. But

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253. What is longitude? How many degrees of longitude are there, east or west? What is the latitude of any place? What is the longitude of a place? 254. Why are the degrees of latitude reckoned from the equator? What is said concerning the places from which the degrees of longitude have been reckoned? What is the inconvenience of estimating longitude from a place in each country? From what place is longitude reckoned in Europe and America?

from east to west there is no natural division of the Earth, each meridian line being a great circle, dividing the Earth into two hemispheres, and hence there is no natural reason why longitude should be reckoned from one meridian any more than another. It has, therefore, been customary for writers and mariners to reckon longitude from the capital of their own country; as the English from London, the French from Paris, and the Americans from Washington. But this mode, it is apparent, must occasion much confusion, since each writer of a different nation would be obliged to correct the longitude of all other countries, to make it agree with his own. More recently, therefore, the writers of Europe and America have selected the royal observatory, at Greenwich, near London, as the first meridian, and on most maps and charts lately published, longitude is reckoned from that place.

255. *How Latitude is Found.*—The latitude of any place is determined by taking the altitude of the Sun at mid-day, and then subtracting this from 90 degrees, making proper allowances for the Sun's place in the heavens. The reason of this will be understood, when it is considered that the whole number of degrees from the zenith to the horizon is 90, and therefore if we ascertain the Sun's distance from the horizon, that is, his altitude, by allowing for the Sun's declination north or south of the equator, and subtracting this from the whole number, the latitude of the place will be found. Thus, suppose that on the 20th of March, when the Sun is at the equator, his altitude from any place north of the equator should be found to be 48 degrees above the horizon; this, subtracted from 90, the whole number of the degrees of latitude, leaves 42, which will be the latitude of the place where the observation was made.

256. If the Sun, at the time of observation, has a declination north or south of the equator, this declination must be added to, or subtracted from, the meridian altitude, as the case may be. For instance, another observation being taken at the place where the latitude was found to be 42, when the Sun had a declination of 8 degrees north, then his altitude would be 8 degrees greater than before, and therefore 56, instead of 48. Now, subtracting this 8, the Sun's declination, from 56, and the remainder from 90, and the latitude of the place will be found 42, as before. If the Sun's declination be south of the equator,

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255. How is the latitude of a place determined? Give an example of the method of finding the latitude of the same place at different seasons of the year? 256. When must the Sun's declination from the equator be added to, and when subtracted from, his meridian altitude?

and the latitude of the place north, his declination must be added to the meridian altitude instead of being subtracted from it. The same result may be obtained by taking the meridian altitude of any of the fixed stars, whose declinations are known, instead of the Sun's, and proceeding as above directed.

257. *How Longitude is Found.*—There is more difficulty in ascertaining the degrees of longitude, than those of latitude, because, as above stated, there is no fixed point, like that of the equator, from which its degrees are reckoned. The degrees of longitude are therefore estimated from Greenwich, and are ascertained by the following methods:—

258. When the Sun comes to the meridian of any place, it is noon, or 12 o'clock, at that place, and therefore, since the equator is divided into 360 equal parts, or degrees, and since the Earth turns on its axis once in 24 hours, 15 degrees of the equator will correspond with one hour of time, for 360 degrees being divided by 24 hours, will give 15. The Earth, therefore, moves in her daily revolution, at the rate of 15 degrees for every hour of time. Now, as the apparent course of the Sun is from east to west, it is obvious that he will come to any meridian lying east of a given place, sooner than to one lying west of that place, and therefore it will be 12 o'clock to the east of any place, sooner than at that place, or to the west of it.

259. When, therefore, it is noon at any one place, it will be 1 o'clock at all places 15 degrees to the east of it, because the Sun was at the meridian of such places an hour before; and so, on the contrary, it will be 11 o'clock, 15 degrees west of the same place, because the Sun has still an hour to travel before he reaches the meridian of that place. It makes no difference, then, where the observer is placed, since, if it is 12 o'clock where he is, it will be 1 o'clock 15 degrees to the east of him, and 11 o'clock 15 degrees to the west of him, and so in this proportion, let the time be more or less. Now, if any celestial phenomenon should happen, such as an eclipse of the Moon, or of Jupiter's satellites, the difference of longitude between two places where it is observed, may be determined by the difference of the times at which it appeared to take place. Thus, if the Moon enters the Earth's shadow at 6 o'clock in the evening, as seen at Philadelphia, and at half past 6 o'clock at another

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257. Why is there more difficulty in ascertaining the degrees of longitude than of latitude? 258. How many degrees of longitude does the surface of the Earth pass through in an hour? 259. Suppose it is noon at any given place, what o'clock will it be fifteen degrees to the east of that place? Explain the reason. How may longitude be determined by an eclipse?

THE TIDES.

243. *The ebbing and flowing of the sea, which regularly takes place twice in 24 hours, are called the tides.*

244. The cause of the tides, is the attraction of the Sun and Moon, but chiefly of the Moon, on the waters of the ocean. In virtue of the universal principle of gravitation, heretofore explained, the Moon, by her attraction, draws, or raises the water toward her, but because the power of attraction diminishes as the squares of the distances increase, the waters, on the opposite side of the Earth, are not so much attracted as they are on the side nearest the Moon.

245. The want of attraction, together with the greater centrifugal force of the Earth on its opposite side, produced in consequence of its greater distance from the common center of gravity, between the Earth and Moon, causes the waters to rise on the opposite side, at the same time that they are raised by direct attraction on the side nearest the Moon.

Thus the waters are constantly elevated on the sides of the Earth opposite to each other above their common level, and consequently depressed at opposite points equally distant from these elevations.

FIG. 257.

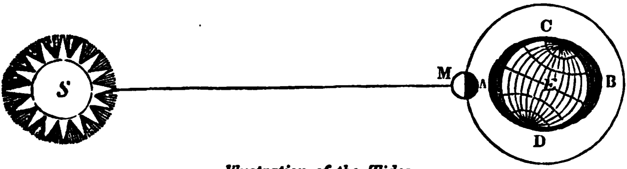

Illustration of the Tides.

246. Let M, *Fig.* 257, be the Moon, and E the Earth, covered with water. As the Moon passes round the Earth, its solid and fluid parts are equally attracted by her influence according to their densities; but while the solid parts are at liberty to move only as a whole, the water obeys the slightest impulse, and thus tends toward the Moon where her attraction is the strongest. Consequently, the waters are perpetually elevated immediately under the Moon.

247. If, therefore, the Earth stood still, the influence of the

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243. What are the tides? 244. What is the cause of the tides? 245. What causes the tide to rise on the side of the Earth opposite to the Moon? 246. Explain Fig. 257. 247. If the Earth stood still, the tides would rise only as the Moon passes round the Earth; what then causes the tides to rise twice in 24 hours?

tude. About 2,000 stars may be seen with the naked eye in the whole vault of the heavens, though only about 1,000 are above the horizon at the same time. Of these, about 17 are of the first magnitude, 50 of the second magnitude, and 150 of the third magnitude. The others are of the fourth, fifth, and sixth magnitudes, the last of which are the smallest that can be distinguished with the naked eye.

263. It might seem incredible, that on a clear night only about 1,000 stars are visible, when on a single glance at the different parts of the firmament, their numbers appear innumerable. But this deception arises from the confused and hasty manner in which they are viewed; for if we look steadily on a particular portion of sky, and count the stars contained within certain limits, we shall be surprised to find their number so few.

264. The nearest fixed stars to our system, from the most accurate astronomical calculations, can not be nearer than 20,000,000,000,000, or 20 trillions of miles from the Earth, a distance so immense, that light can not pass through it in less than three years. Hence, were these stars annihilated at the present time, their light would continue to flow toward us, and they would appear to be in the same situation to us, three years hence, that they do now.

265. Our Sun, seen from the distance of the nearest fixed stars, would appear no larger than a star of the first magnitude does to us. These stars appear no larger to us, when the Earth is in that part of her orbit nearest to them, than they do, when she is in the opposite part of her orbit; and as our distance from the Sun is 95,000,000 of miles, we must be twice this distance, or the whole diameter of the Earth's orbit, nearer a given fixed star at one period of the year than at another. The difference, therefore, of 190,000,000 of miles, bears so small a proportion to the whole distance between us and the fixed stars, as to make no appreciable difference in their sizes, even when assisted by the most powerful telescopes.

266. The amazing distances of the fixed stars may also be inferred from the return of comets to our system, after an absence of several hundred years.

The velocity with which some of these bodies move, when

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263. Why does there appear to be more stars than there really are? 264. What is the computed distance of the nearest fixed stars from the Earth? How long would it take light to reach us from the fixed stars? 265. How large would our Sun appear at the distance of the fixed stars? What is said concerning the difference of the distance between the Earth and the fixed stars at different seasons of the year, and of their different appearance in consequence? 266. How may the distances of the fixed stars be inferred, by the long absence and return of comets?

nearest the Sun, has been computed at nearly a million of miles in an hour, and although their velocities must be perpetually retarded, as they recede from the Sun, still, in 250 years of time, they must move through a space which to us would be infinite. The periodical return of one comet is known to be upward of 500 years, making more than 250 years in performing its journey to the most remote part of its orbit, and as many in returning back to our system; and that it must still always be nearer our system than the fixed stars, is proved by its return; for by the laws of gravitation, did it approach nearer another system it would never again return to ours.

267. From such proofs of the vast distances of the fixed stars, there can be no doubt that they shine with their own light, like our Sun, and hence the conclusion that they are Suns to other worlds, which move around them, as the planets do around our Sun. Their distances will, however, prevent our ever knowing, except by conjecture, whether this is the case or not, since, were they millions of times nearer us than they are, we should not be able to discover the reflected light of their planets.

COMETS.

268. Besides the planets, which move round the Sun in regular order and in nearly circular orbits, there belongs to the solar system an unknown number of bodies called *Comets*, which move round the Sun in orbits exceedingly eccentric, or elliptical, and whose appearance among our heavenly bodies is only occasional. Comets, to the naked eye, have no visible disc, but shine with a faint, glimmering light, and are accompanied by a train or tail, turned from the Sun, and which is sometimes of immense length. They appear in every region of the heavens, and move in every possible direction.

269. *Number and Periods of Comets.*—The number of comets is unknown, though some astronomers suppose that there are nearly 500 belonging to our system. Ferguson, who wrote in about 1760, supposed that there were less than 30 comets which made us occasional visits; but since that period the elements of the orbits of nearly 100 of these bodies have been computed.

Of these, however, there are only three whose periods of return among us are known with any degree of certainty. The

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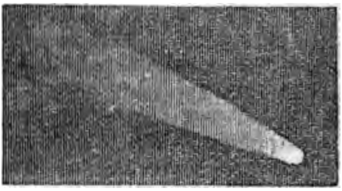
267. On what grounds is it supposed that the fixed stars are suns to other worlds?
269. What number of comets are supposed to belong to our system?

FIG. 260.



Comet of 1680.

first of these has a period of 75 years; the second a period of 129 years; and the third a period of 575 years. The third appeared in 1680, and therefore can not be expected again until the year 2225. This comet, *Fig.* 260, in 1680, excited the most intense interest among the astronomers of Europe, on account of its great apparent size and near approach to our system. In the most remote part of its orbit, its distance from the Sun was estimated at about 11,200,000,000 of miles. At its nearest approach to the Sun, which was only about 50,000 miles, its velocity, according to Sir Isaac Newton, was 880,000 miles in an hour; and supposing it to have retained the Sun's heat, like other solid bodies, its temperature must have been about 2,000 times that of red hot iron. The tail of this comet was at least 100,000,000 of miles long.

270. In the Edinburgh Encyclopedia, article *Astronomy*, there is the most complete table of comets yet published. This table contains the elements of 97 comets, calculated by different astronomers, down to the year 1808.

From this table it appears that 24 comets have passed between the Sun and the orbit of Mercury; 33 between the orbits of Venus and the Earth; 15 between the orbits of the Earth and Mars; 3 between the orbits of Mars and Ceres; and 1 between the orbits of Ceres and Jupiter. It also appears by this table that 49 comets have moved round the Sun from west to east, and 48 from east to west.

271. *Nature of Comets.*—Of the nature of these wandering planets very little is known. When examined by a telescope, they appear like a mass of vapors surrounding a dark nucleus. When the comet is at its perihelion, or nearest the Sun, its color seems to be heightened by the intense light or heat of that luminary, and it then often shines with more brilliancy than the planets. At this time the tail or train, which is always directly opposite to the Sun, appears at its greatest length, but is commonly so transparent as to permit the fixed stars to be

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270. How many have had the elements of their orbits estimated by astronomers? How many are there whose periods of return are known? 271. What is said of the comet of 1680?

seen through it. A variety of opinions have been advanced by astronomers concerning the nature and causes of these trains, but no satisfactory theory has been offered.

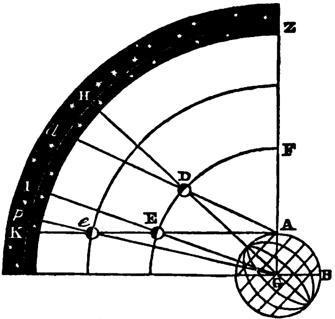
A new comet was discovered by Miss Maria Mitchell, of Nantucket, in October, 1847, for which she received the gold medal of the king of Denmark, offered for the first discovery of a new comet in any country.

PARALLAX.

272. Parallax is the difference between the true and apparent place of a celestial body. The *apparent* place is that in which the body seems to be when viewed from the surface of the Earth, the *true* place being that in which it would appear if seen from the center of the earth.

This will be understood by *Fig.* 261, where if we suppose a spectator placed at G, in the Earth's center, he would see the moon E, among the stars at I, whereas without changing the position of the moon, if that body is seen from A, on the surface of the Earth, it would appear among the stars at K. Now I is the *true* and K the *apparent* place of the moon, the space between them, being the Moon's parallax.

FIG. 261.



Diurnal Parallax.

The parallax of a body is greatest when on the sensible horizon, (170,) or at the moment when it becomes visible to the eye. From this point it diminishes until it reaches the zenith, or the highest place in the heavens, when its parallax ceases entirely. Thus it will be seen by the figure, that the parallax of the moon is less when at D, than it was at E, and that when it arrives at the zenith, Z, its position is the same whether seen from the center of the Earth, G, or from its surface, A.

The greater the distance of the heavenly body from the spectator, the less is its parallax.

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272. What is parallax? What is the apparent place of a celestial body? What is the true place of such a body? Explain Fig. 261, and show why there is no parallax when the body is in the zenith?

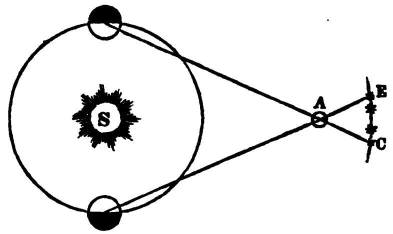
Thus were the Moon at *e* instead of at E, her parallax would be only equal to *p* K, instead of I K. Hence the Moon, being the nearest celestial body, has the greatest parallax, the difference of her place among the stars, when seen from the surface of the Earth, A, and the center G, being about 4,000 miles.

273. *Parallax of the Stars.*—The stars are at such immense distances from the Earth, that the difference of situation between the center and surface of the Earth makes no perceptible change in their places, and hence they have no parallax.

274. *Diurnal Parallax.*—This applies to the solar system, and takes place every day in the apparent rotation of the planets around the Earth. The Moon, as above shown, has a parallax when she rises, which diminishes until she reaches the zenith, when it ceases entirely; the same is the case with the Sun and planets, which have sensible parallaxes.

275. *Annual Parallax.*—This is the difference in the apparent places of the celestial bodies, as seen from the Earth at the opposite points of her orbit, during her annual revolution round the Sun.

FIG. 262.



Annual Parallax.

Suppose A, *Fig.* 262, to be a stationary celestial object, then as the Earth makes her annual revolution around the Sun S, this object at one time will appear among the stars at E, but six months after, when the Earth comes to the opposite point in her orbit, the same object will be seen at C, the space from C to E being the annual parallax of the object A. But the distances of the stars are so great that the diameter of the Earth's orbit, or 190,000,000 of miles make no difference in their apparent places. Were the fixed stars within 19,000,000,000,000, or 19 trillions of miles, their distance could be told by their parallaxes.

But since, as above stated, these celestial points have no sensible parallaxes, their distances must be greater than this, but how much is unknown.

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273. Why have the stars no parallaxes? 274. What is diurnal parallax? 275. What is annual parallax?

place, then this place is half an hour, or 7½ degrees, to the east of Philadelphia, because 7½ degrees of longitude are equal to half an hour of time. To apply these observations practically, it is only necessary that it should be known exactly at what time the eclipse takes place at a given point on the Earth.

260. Use of the Chronometer.—Suppose two chronometers, which are known to go at exactly the same rate, are made to indicate 12 o'clock by the meridian line at Greenwich, and the one be taken to sea, while the other remains at Greenwich. Then suppose the captain, who takes his chronometer to sea, has occasion to know his longitude. In the first place, he ascertains, by an observation of the Sun, when it is 12 o'clock at the place where he is, and then by his time-piece, when it is 12 o'clock at Greenwich, and by allowing 15 degrees for every hour of the difference in time, he will know his precise longitude in any part of the world.

261. For example, suppose the captain sails with his chronometer for America, and after being several weeks at sea, finds by observation that it is 12 o'clock by the Sun, and at the same time finds by his chronometer, that it is 4 o'clock at Greenwich. Then, because it is noon at his place of observation after it is noon at Greenwich, he knows that his longitude is west from Greenwich, and by allowing 15 degrees for every hour of the difference, his longitude is ascertained. Thus, 15 degrees, multiplied by 4 hours, give 60 degrees of west longitude from Greenwich. If it is noon at the place of observation, before it is noon at Greenwich, then the captain knows that his longitude is east, and his true place is found in the same manner.

FIXED STARS.

262. *The stars are called fixed, because they have been observed not to change their places with respect to each other.* They may be distinguished by the naked eye from the planets of our system by their scintillations, or twinkling. The stars are divided into classes, according to their magnitudes, and are called stars of the first, second, and so on to the sixth magni-

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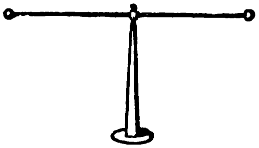
260. Explain the principles on which longitude is determined by the chronometer. 261. Suppose the captain finds by his chronometer that it is 12 o'clock where he is, 4 hours later than at Greenwich, what then would be his longitude? Suppose he finds it to be 12 o'clock 4 hours earlier where he is, than at Greenwich, what then would be his longitude? 262. Why are the stars called fixed? How may the stars be distinguished from the planets? The stars are divided into classes, according to their magnitudes; how many classes are there? How many stars may be seen with the naked eye in the whole firmament?

electricity, and for obtaining indications of its presence, when it exists only in a feeble degree. Instruments for this purpose are termed *Electroscopes.*

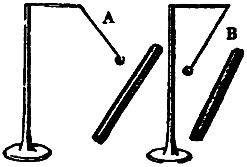
One of the simplest instruments of this kind consists of a metallic needle, terminated at each end by a light pith-ball, which is covered with gold leaf, and supported horizontally at its center by a fine point, *Fig.* 263. When a stick of sealing-wax, or a glass tube, is excited, and then presented to one of these balls, the motion of the needle on its pivot will indicate the electrical influence.

FIG. 263.



Electroscope.

FIG. 264.



Electrical Attraction.

279. If an excited substance be brought near a ball made of pith, or cork, suspended by a silk thread, the ball will, in the first place, approach the electric, as at A, *Fig.* 264, indicating an attraction toward it, and if the position of the electric will allow, the ball will come into contact with the electric, and adhere to it for a short time, and will then recede from it, showing that it is repelled, as at B. If, now, the ball which had touched the electric, be brought near another ball, which has had no communication with an excited substance, these two balls will attract each other, and come into contact; after which they will repel each other, as in the former case.

It appears, therefore, that the excited body, as the stick of sealing-wax, imparts a portion of its electricity to the ball, and that when the ball is also electrified, a mutual repulsion then takes place between them. Afterwards, the ball, being electrified by contact with the electric, when brought near another ball not electrified, transfers a part of its electrical influence to that, after which these two balls repel each other, as in the former instance.

280. Thus, when one substance has a greater or less quan-

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279. When do two electrified bodies attract, and when do they repel each other? 280. How will two bodies act, one having more, and the other less, than the natural quantity of electricity, when brought near each other? How will they act when both have more or less than their natural quantity?

tity of electricity than another, it will attract the other substance, and when they are in contact will impart to it a portion of this superabundance; but when they are both equally electrified, both having more or less than their natural quantity of electricity, they will repel each other.

Electrical Theories.—To account for these phenomena, two theories have been advanced, one by Dr. Franklin, who supposes there is only one electrical fluid, and the other by Du Fay, who supposes that there are two distinct fluids.

281. *Franklin's Theory.*—Dr. Franklin supposed that all terrestrial substances were pervaded with the electrical fluid, and that by exciting an electric, the equilibrium of this fluid was destroyed, so that one part of the excited body contained more than its natural quantity of electricity, and the other part less. If in this state a conductor of electricity, as a piece of metal, be brought near the excited part, the accumulated electricity would be imparted to it, and then this conductor would receive more than its natural quantity of the electric fluid. This he called *positive* electricity. But if a conductor be connected with that part which has less than its ordinary share of the fluid, then the conductor parts with a share of its own, and therefore will then contain less than its natural quantity. This he called *negative* electricity. When one body *positively* and another *negatively* electrified, are connected by a conducting substance, the fluid rushes from the positive to the negative body, and the equilibrium is restored. Thus, bodies which are said to be positively electrified, contain more than their natural quantity of electricity, while those which are negatively electrified, contain less than their natural quantity.

282. *Du Fay's Theory.*—The other theory is explained thus. When a piece of glass is excited and made to touch a pith-ball, as above stated, then that ball will attract another ball, after which they will mutually repel each other, and the same will happen if a piece of sealing-wax be used instead of the glass. But if a piece of excited glass, and another of wax, be made to touch two separate balls, they will attract each other; that is, the ball which received its electricity from the wax will attract that which received its electricity from the glass, and will be

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281. Explain Dr. Franklin's theory of electricity. What is meant by positive, and what by negative electricity? What is the consequence, when a positive and a negative body are connected by a conductor? 282. Explain Du Fay's theory. When two balls are electrified, one with glass and the other with wax, will they attract or repel each other? What are the two electricities called? From what substances are the two electricities obtained?

attracted by it. Hence Du Fay concludes that electricity consists of two distinct fluids, which exist together in all bodies—that they have a mutual attraction for each other—that they are separated by the excitation of electrics, and that when thus separated, and transferred to non-electrics, as to the pith-balls, their mutual attraction causes the balls to rush toward each other. These two principles he called *vitreous* and *resinous* electricity. The vitreous being obtained from glass, and the resinous from wax and other resinous substances.

Dr. Franklin's theory is by far the most simple, and will account for most of the electrical phenomena equally well with that of Du Fay, and therefore has been adopted by the most able and recent electricians.

283. It is found that some substances conduct the electric fluid from a positive to a negative surface with great facility, while others conduct it with difficulty, and others not at all. Substances of the first kind are called *conductors*, and those of the last *non-conductors*. The electrics, or such substances as being excited, communicate electricity, are all non-conductors, while the non-electrics, or such substances as do not communicate electricity on being merely excited, are conductors. The conductors are the metals, charcoal, water, and other fluids, except the oils; also smoke, steam, ice, and snow. The best conductors are gold, silver, platina, brass, and iron.

The electrics, or non-conductors, are glass, amber, sulphur, resin, wax, silk, most hard stones, and the furs of some animals.

A body is said to be *insulated*, when it is supported or surrounded by an electric. Thus, a stool standing on glass legs, is insulated, and a plate of metal laid on a plate of glass, is insulated.

284. *Electrical Machines.*—When large quantities of the electric fluid are wanted for experiment, or for other purposes, it is procured by an *electrical machine*. These machines are of various forms, but all consist of an *electric* substance of considerable dimensions; the *rubber* by which this is excited; the *prime conductor*, on which the electric matter is accumulated; the *insulator*, which prevents the fluid from escaping; and machinery, by which the electric is set in motion.

Formerly a glass cylinder was employed as an electric, but

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283. What are conductors? What are non-conductors? What substances are conductors? What substances are the best conductors? What substances are electrics, or non-conductors? When is a body said to be insulated? 284. What are the several parts of an electrical machine?

more recently, round, flat plates of glass, called *plate machines*, are used instead of cylinders. This is a great improvement, since both sides of the plate are exposed to electrical friction, while in the cylinder, the outside only could be excited.

This machine is represented by *Fig.* 265, and consists of a circular plate of glass, from one to two or three feet in diameter, turning on an axis of wood which passes through its center. The plate is rubbed as it revolves, by two leather cushions, A and B, fixed at opposite points of its circumference, and by means of elastic slips of wood adjusted by screws, made to press on its surface. On the opposite side are two other cushions not seen, the plate revolving between them. A hollow brass prime conductor, C, supported by a glass standard D, is attached to the frame of the machine. On each side of the conductor are branches of the same metal, at the ends of which are sharp wires nearly touching the glass plate, and by means of which the electric fluid is collected and conveyed to the conductor.

FIG. 265.

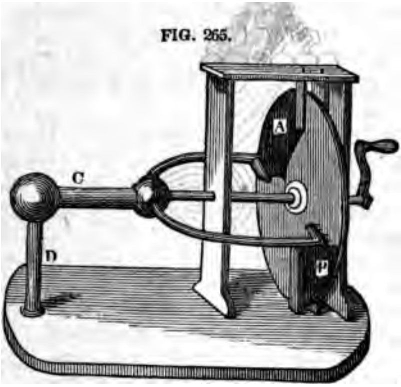

Plate Electrical Machine.

285. *Mode of Action.*—The manner in which this machine acts is easily understood. The friction of the cushions against the glass plate, transfers the electrical fluid from the cushions to the glass, so that while the glass becomes positive, the cushions become negative. Meantime, the fluid, which adheres to the surface of the glass, is attracted by the metallic points and

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Describe the electrical machine, Fig. 265. 285. Whence comes the electricity, when the plate is turned? Why is it necessary to throw the chain on the ground to obtain more electricity?

conveyed to the prime conductor, which being insulated by the glass standard, the electricity is there accumulated in quantities proportionate to the surface of the conductor.

If the cushions are insulated, the quantity of electricity obtained is limited, consisting of that, merely, which the cushions contained, and when this is transferred to the plate, no more can be obtained. It is then necessary to make the cushions communicate with the ground, the great reservoir of electricity, by laying the chain attached to the cushions on the floor or table, when on again turning the machine, more of the fluid will be conveyed to the conductor.

286. If a person who is insulated takes the chain in his hand, the electric fluid will be drawn from him, along the chain, to the cushion, and from the cushion will be transferred to the prime conductor, and thus the person will become negatively electrified. If, then, another person, standing on the floor, hold his knuckle near him who is insulated, a spark of electric fire will pass between them, with a crackling noise, and the equilibrium will be restored; that is, the electric fluid will pass from him who stands on the floor, to him who stands on the stool. But if the insulated person takes hold of a chain, connected with the prime conductor, he may be considered as forming a part of the conductor, and therefore the electric fluid will be accumulated all over his surface, and he will be positively electrified, or will obtain more than his natural quantity of electricity. If now a person standing on the floor touch this person, he will receive a spark of electrical fire from him, and the equilibrium will again be restored.

287. If two persons stand on two insulated stools, or if they both stand on a plate of glass, or a cake of wax, the one person being connected by the chain with the prime conductor, and the other with the cushion, then, after working the machine, if they touch each other, a much stronger shock will be felt than in either of the other cases, because the difference between their electrical states will be greater, the one having more and the other less than his natural quantity of electricity. But if the two insulated persons both take hold of the chain connected with the prime conductor, or with that connected with the

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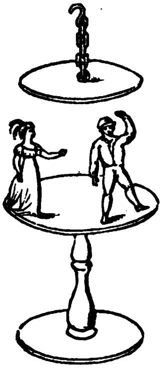
286. If an insulated person takes the chain, connected with the cushion, in his hand, what change will be produced in his natural quantity of electricity? If the insulated person takes hold of the chain connected with the prime conductor, and the machine be worked, what then will be the change produced in his electrical state? 287. If two insulated persons take hold of the two chains, one connected with the prime conductor, and the other with the cushion, what changes will be produced? If an insulated person takes the chain, what effect will it produce on him?

cushion, no spark will pass between them, on touching each other, because they will then both be in the same electrical state.

288. We have seen, *Fig.* 264, that the pith-ball is first attracted and then repelled, by the excited electric, and that the ball so repelled will attract, or be attracted by other substances in its vicinity, in consequence of having received from the excited body more than its ordinary quantity of electricity.

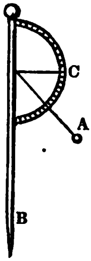
These alternate movements are amusingly exhibited by placing some small light bodies, such as the figures of men and women, made of pith, or paper, between two metallic plates, the one placed over the other, as in *Fig.* 266, the upper plate communicating with the prime conductor, and the other with the ground. When the electricity is communicated to the upper plate, the little figures, being attracted by the electricity, will jump up and strike their heads against it, and having received a portion of the fluid, are instantly repelled, and again attracted by the lower plate, to which they impart their electricity, and then are again attracted, and so fetch and carry the electric fluid from one to the other, as long as the upper plate contains more than the lower one. In the same manner, a tumbler, if electrified on the inside, and placed over light substances, as pith-balls, will cause them to dance for a considerable time.

FIG. 266.



Attraction and Repulsion.

FIG. 267.



Electrometer.

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288. Explain the reason why the little images dance between the two metallic plates, Fig. 266.

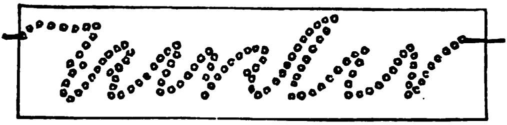
289. *Electrometer.*—Instruments designed to measure the intensity of electric action, are called *Electrometers.* Such an instrument is represented by *Fig.* 267. It consists of a slender rod of light wood, A, terminated by a pith-ball, which serves as an index. This is suspended at the upper part of the wooden stem, B, so as to play easily backward and forward. The ivory semicircle C, is affixed to the stem, having its center coinciding with the axis of motion of the rod, so as to measure the angle of deviation from the perpendicular, which the repulsion of the ball from the stem produces on the index.

When this instrument is used, the lower end of the stem is set into an aperture in the prime conductor, and the intensity of the electric action is indicated by the number of degrees the index is repelled from the perpendicular.

The passage of the electric fluid through a perfect conductor is never attended with light, or the crackling noise which is heard when it is transmitted through the air, or along the surface of an electric.

290. Several curious experiments illustrate this principle, for if fragments of tin foil, or other metal, be pasted on a piece of glass, so near each other that the electric fluid can pass between them, the whole line thus formed with the pieces of metal, will be illuminated by the passage of the electricity from one to the other.

FIG. 268.



Franklin.

In this manner figures or words may be formed, as in *Fig.* 268, which, by connecting one of its ends with the prime conductor, and the other with the ground, will, when the electric fluid is passed through the whole, in the dark, appear one continuous and vivid line of fire.

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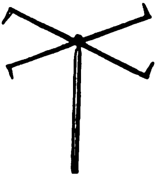
289. What is an electrometer? Describe that represented in Fig. 267, together with the mode of using it. When the electric fluid passes along a perfect conductor is it attended with light or not? When it passes along an electric, or through the air, what phenomena does it exhibit? 290. Describe the experiment, Fig. 268, intended to illustrate this principle.

291. *Electrical Light.*—Electrical light seems not to differ, in any respect, from the light of the Sun, or of a burning lamp. Dr. Wollaston observed, that when this light was seen through a prism, the ordinary colors arising from the decomposition of light were obvious.

292. When the electric fluid is discharged from a point, it is always accompanied by a current of air, whether the electricity be positive or negative. The reason of this appears to be, that the instant a particle of air becomes electrified, it repels, and is repelled, by the point from which it received the electricity.

FIG. 269.



Several curious little experiments are made on this principle. Thus, let two cross wires, as in *Fig.* 269, be suspended on a pivot, each having its point bent in a contrary direction, and electrified by being placed on the prime conductor of a machine. These points, so long as the machine is in action, will give off streams of electricity; and as the particles of air repel the points by which they are electrified, the little machine will turn round rapidly, in the direction contrary to that of the stream of electricity. Perhaps, also, the reaction of the atmosphere against the current of air given off by the points, assists in giving it motion.

293. *Leyden Vials.*—When one part or side of an electric is positively, the other part or side is negatively electrified. Thus, if a plate of glass be positively electrified on one side, it will be negatively electrified on the other, and if the inside of a glass vessel be positive, the outside will be negative.

Advantage of this circumstance is taken, in the construction of electrical jars, called from the place where they were first made, *Leyden vials.*

The most common form of this jar is represented by *Fig.* 270. It consists of a glass vessel, coated on both sides up to A, with tin foil; the upper part being left naked, so as to prevent a spontaneous discharge, or the passage of the electric fluid from one coating to the other. A metallic rod, rising two or three inches above the jar, and terminated at the top with a

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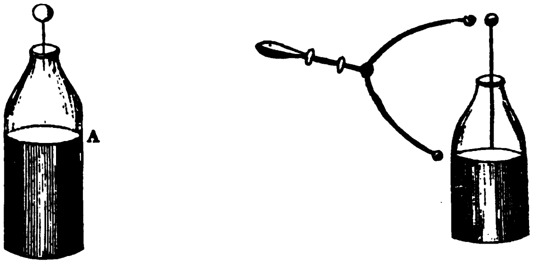
291. What is the appearance of electrical light through a prism? 292. Describe Fig. 269, and explain the principle on which its motion depends. 293. Suppose one part or side of an electric is positive, what will be the electrical state of the other side or part? What part of the electrical apparatus is constructed on this principle? How is the Leyden vial constructed? Why is not the whole surface of this vial covered with the tin foil?

brass ball, which is called the *knob* of the jar, is made to descend through the cover, till it touches the interior coating. It is along this rod that the charge of electricity is conveyed to the inner coating, while the outer coating is made to communicate with the ground.

FIG. 270. FIG. 271.



Leyden Jars.

294. When a chain is passed from the prime conductor of an electrical machine to this rod, the electricity is accumulated on the tin foil coating, while the glass above the tin foil prevents its escape, and thus the jar becomes charged. By connecting together a sufficient number of these jars, any quantity of the electric fluid may be accumulated. For this purpose, all the interior coatings of the jars are made to communicate with each other, by metallic rods passing between them, and finally terminating in a single rod. A similar union is also established, by connecting the external coats with each other. When thus arranged, the whole series may be charged, as if they formed but one jar, and the whole series may be discharged at the same instant. Such a combination of jars is termed an *electrical battery.*

295. For the purpose of making a direct communication between the inner and outer coating of a single jar, or battery, by which a discharge is effected, an instrument called a *discharging-rod* is employed. It consists of two bent metallic rods, terminated at one end by brass balls, and at the other end connected by a joint. This joint is fixed to the end of a glass

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294. How is a Leyden vial charged? In what manner may a number of these vials be charged? What is an electrical battery? 295. Explain the design of Fig. 271, and show how an equilibrium is produced by the discharging-rod.

handle, and the rods being movable at the joint, the balls can be separated or brought near each other, as occasion requires. When opened to a proper distance, one ball is made to touch the tin foil on the outside of the jar, and then the other is brought into contact with the knob of the jar, as seen in *Fig.* 271. In this manner a discharge is effected, or an equilibrium produced between the positive and negative sides of the jar.

296. When it is desired to pass the charge through any substance for experiment, then an *electrical circuit* must be established, of which the substance to be experimented upon must form a part. That is, the substance must be placed between the ends of two metallic conductors, one of which communicates with the positive, and the other with the negative side of the jar, or battery.

297. When a person takes the electrical shock in the usual manner, he merely takes hold of the chain connected with the outside coating, and the battery being charged, touches the knob with his finger, or with a metallic rod. On making this circuit, the fluid passes through the person from the positive to the negative side.

Any number of persons may receive the electrical shock, by taking hold of each other's hand, the first person touching the knob, while the last takes hold of a chain connected with the external coating. In this manner, hundreds, or, perhaps, thousands of persons, will feel the shock at the same instant, there being no perceptible interval in the time when the first and the last person in the circle feels the sensation excited by the passage of the electric fluid.

298. *Atmospheric Electricity.*—The atmosphere always contains more or less electricity, which is sometimes positive, and at others negative. It is, however, most commonly positive, and always so when the sky is clear or free from clouds or fogs. It is always stronger in winter than in summer, and during the day than during the night. It is also stronger at some hours of the day than at others; being strongest about 9 o'clock in the morning, and weakest about the middle of the afternoon. These different electrical states are ascertained by means of long

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296. When it is desired to pass the electrical fluid through any substance, where must it be placed in respect to the two sides of the battery? 297. Suppose the battery is charged, what must a person do to take the shock? What circumstance is related, which shows the surprising velocity with which electricity is transmitted? 298. Is the electricity of the atmosphere positive or negative? At what times does the atmosphere contain most electricity? How are the different electrical states of the atmosphere ascertained?

metallic wires extending from one building to another, and connected with electrometers.

299. It was proved by Dr. Franklin, that the electric fluid and *lightning* are the same substance, and this identity has been confirmed by subsequent writers on this subject.

If the properties and phenomena of lightning be compared with those of electricity, it will be found that they differ only in respect to degree. Thus, lightning passes in irregular lines through the air; the discharge of an electrical battery has the same appearance. Lightning strikes the highest pointed objects—takes in its course the best conductors—sets fire to non-conductors, or rends them in pieces, and destroys animal life; all of which phenomena are caused by the electric fluid.

300. LIGHTNING RODS.—Buildings may be secured from the effects of lightning, by fixing to them a metallic rod, which is elevated above any part of the edifice and continued to the moist ground, or to the nearest water. Copper, for this purpose, is better than iron, not only because it is less liable to rust, but because it is a better conductor of the electric fluid. The upper part of the rod should end in several fine points, which must be covered with some metal not liable to rust, such as gold, platina, or silver.

301. *No protection is afforded by the conductor, unless it is continued without interruption from the top to the bottom of the building, and it can not be relied on as a protector, unless it reaches the moist earth, or ends in water connected with the earth.* Conductors of copper may be three-fourths of an inch in diameter, but those of iron should be at least an inch in diameter. In large buildings, complete protection requires many lightning rods, or that they should be elevated to a height above the building in proportion to the smallness of their numbers, for modern experiments have proved that a rod only protects a circle around it, *the radius of which is equal to twice its length above the building.*

302. Thus a rod 20 feet above the building, will protect a space of 40 feet from it in all directions.

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299. Who first discovered that electricity and lightning are the same? What phenomena are mentioned which belong in common to electricity and lightning? 300. How may buildings be protected from the effects of lightning? Which is the best conductor, iron or copper? 301. What circumstances are necessary, that the rod may be relied on as a protector? 302. What diameter will a rod 20 feet above the building protect?

CHAPTER XIV.

MAGNETISM.

303. *The native Magnet, or Loadstone, is an ore of iron, which is found in various parts of the world. Its color is iron black; its specific gravity from 4 to 5, and it is sometimes found in crystals.*

This substance, without any preparation, attracts iron and steel, and when suspended by a string, will turn one of its sides toward the north, and another toward the south.

It appears that an examination of the properties of this species of iron ore, led to the important discovery of the magnetic needle, and subsequently laid the foundation for the science of magnetism; though at the present day magnets are made without this article.

304. The whole science of magnetism is founded on the fact, that pieces of iron or steel, after being treated in a certain manner, and then suspended, will constantly turn one of their ends toward the north, and consequently the other toward the south. The same property has been more recently proved to belong to the metals *nickel* and *cobalt*, though with much less intensity.

305. Still more recently, it has been found by Prof. Faraday, that when a strong electro-magnet is employed, the following metals are acted upon with varying intensity, and therefore must be added to the list of magnetic metals, viz., *manganese*, *chromium*, *cerium*, *titanium*, *palladium*, *platinum*, and *osmium*.

306. The *poles* of a magnet are those parts which possess the greatest power, or in which the magnetic virtue seems to be concentrated. One of the poles points north, and the other south. The *magnetic meridian* is a vertical circle in the heavens, which intersects the horizon at the points to which the magnetic needle, when at rest, directs itself.

307. The *axis* of a magnet, is a right line which passes from one of its poles to the other.

The *equator* of a magnet, is a line perpendicular to its axis, and is at the center between the two poles.

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303. What is the native magnet or loadstone? What are the properties of the loadstone? 304. On what is the whole subject of magnetism founded? What other metals besides iron possess the magnetic property? 305. What metals besides iron, nickel, and cobalt, are magnetic? 306. What are the poles of a magnet? 307. What is the axis of a magnet? What is the equator of a magnet?

308. *Leading Properties.*—The leading properties of the magnet are the following: It attracts iron and steel, and when suspended so as to move freely, it arranges itself so as to point north and south; this is called the *polarity* of the magnet. When the *south* pole of one magnet is presented to the *north* pole of another, they will attract each other; this is called *magnetic attraction.* But if the two north, or two south poles be brought together, they will repel each other, and this is called *magnetic repulsion.*

309. When a magnet is left to move freely, it does not lie in a horizontal direction, but one pole inclines downward, and consequently the other is elevated above the line of the horizon. This is called the *dipping*, or *inclination* of the magnetic needle. Any magnet is capable of communicating its own properties to iron or steel, and this, again, will impart its magnetic virtue to another piece of steel, and so on indefinitely.

310. If a piece of iron or steel be brought near one of the poles of a magnet, they will attract each other, and if suffered to come into contact, will adhere so as to require force to separate them. This attraction is mutual; for the iron attracts the magnet with the same force that the magnet attracts the iron. This may be proved, by placing the iron and magnet on pieces of wood floating on water, when they will be seen to approach each other mutually.

311. *Force of Attraction.*—The force of magnetic attraction varies with the distance in the same ratio as the force of gravity; the attracting force being inversely as the square of the distance between the magnet and the iron.

312. The magnetic force is not sensibly affected by the interposition of any substance except those containing iron, or steel. Thus, if two magnets, or a magnet and piece of iron, attract each other with a certain force, this force will be the same if a plate of glass, wood, or paper, be placed between them. Neither will the force be altered, by placing the two attracting bodies under water, or in the exhausted receiver of an air-pump. This proves that the magnetic influence passes equally well through air, glass, wood, paper, water, and a vacuum.

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308. What is meant by the polarity of a magnet? When do two magnets attract, and when repel each other? 309. What is understood by the dipping of the magnetic needle? 310. How is it proved that the iron attracts the magnet with the same force that the magnet attracts the iron? 311. How does the force of magnetic attraction vary with the distance? 312. Does the magnetic force vary with the interposition of any substance between the attracting bodies?

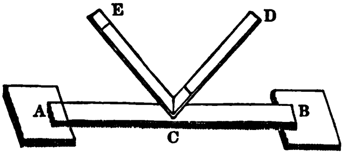
313. *Destroyed by Heat.*—Heat weakens the attractive power of the magnet, and a white heat entirely destroys it. Electricity will change the poles of the magnetic needle, and the explosion of a small quantity of gunpowder on one of the poles, will have the same effect.

314. The attractive power of the magnet may be increased by permitting a piece of steel to adhere to it, and then suspending to the steel a little additional weight every day, for it will sustain, to a certain limit, a little more weight on one day than it would on the day before.

315. Small natural magnets will sustain more than large ones in proportion to their weight. It is rare to find a natural magnet, weighing 20 or 30 grains, which will lift more than thirty or forty times its own weight. But a minute piece of natural magnet, worn by Sir Isaac Newton, in a ring, which weighed only three grains, is said to have been capable of lifting 746 grains, or nearly 250 times its own weight.

316. *Artificial Magnets.*—The magnetic property may be communicated from the loadstone, or artificial magnet, in the following manner, it being understood that the north pole of one of the magnets employed, must always be drawn toward the south pole of the new magnet, and that the south pole of the other magnet employed, is to be drawn in the contrary direction. The north poles of magnetic bars are usually marked with a line across them, so as to distinguish this end from the other.

FIG. 272.



Artificial Magnets.

Place two magnetic bars A and B, *Fig.* 272, so that the north end of one may be nearest the south end of the other, and at such a distance that the ends of the steel bar to be touched, may rest upon them. Having thus arranged them, as shown in the figure, take the two magnetic bars, D and E, and apply the south end of E, and the north end of D, to the middle of the bar C, elevating their ends as seen in the figure. Next separate the bars E and D, by drawing them in opposite directions along the surface of C, still preserving the elevation

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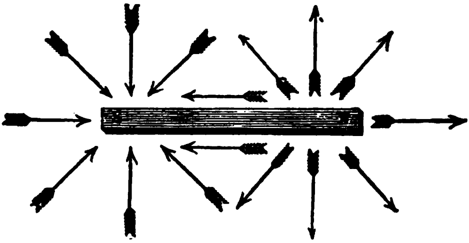
313. What is the effect of heat on the magnet? What is the effect of electricity, or the explosion of gunpowder on it? 314. How may the power of a magnet be increased? 315. What is said concerning the comparative powers of great and small magnets? 316. Explain Fig 272, and describe the mode of making magnet.

of their ends; then removing the bars D and E, to the distance of a foot or more from the bar C, bring their north and south poles into contact, and then having again placed them on the middle, C, draw them in contrary directions, as before. The same process must be repeated many times on each side of the bar, C, when it will be found to have acquired a strong and permanent magnetism.

317. If a bar of iron be placed, for a long period of time, in a north and south direction, or in a perpendicular position, it will often acquire a strong magnetic power. Old tongs, pokers, and fire shovels, almost always possess more or less magnetic virtue; and the same is found to be the case with the iron window bars of ancient houses, whenever they have happened to be placed in the direction of the magnetic line.

318. A *magnetic needle*, such as is employed in the mariner's and surveyor's compass, may be made by fixing a piece of steel on a board, and then drawing two magnets from the center toward each end, as directed at *Fig.* 272. Some magnetic needles, in time, lose their virtue, and require again to be magnetized. This may be done by placing the needle still suspended on its pivot, between the opposite poles of two magnetic bars. While it is receiving the magnetism, it will be agitated, moving backward and forward, as though it were animated; but when it has become perfectly magnetized, it will remain quiescent.

FIG. 273.



Magnetic Rotation.

319. *Magnetic Rotation.*—It is quite interesting to observe the different directions the needle of a small magnetic compass

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317. In what positions do bars of iron become magnetic spontaneously?
318. How may a needle be magnetized without removing from its pivot?

will assume when moved round a bar magnet. If the latter be laid on the table, and the former carried slowly around it, from S, or south, to N, or north, and so back again on the other side, the needle will alternately take all the positions shown by *Fig.* 273.

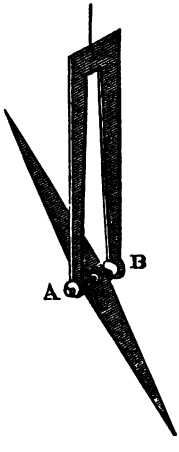
X 320. DIP OF THE MAGNET.—The *dip*, or *inclination* of the magnetic needle, is its deviation from its horizontal position, as already mentioned. A piece of steel, or a needle which will rest on its center, in a direction parallel to the horizon, before it is magnetized, will afterward incline one of its ends toward the earth. This property of the magnetic needle was discovered by a compass-maker, who, having finished his needles before they were magnetized, found that immediately afterward, their north ends inclined toward the earth, so that he was obliged to add small weights to their south poles, in order to make them balance, as before.

321. The dip of the magnetic needle is measured, by a graduated circle, placed in the vertical position, with the needle suspended by its side. Its inclination from a horizontal line, marked across the face of this circle, is the measure of its dip. The circle, as usual, is divided into 360 degrees, and these into minutes and seconds.

322. *Dipping Needle.*—*Fig.* 274 is said to represent a convenient form of the dipping needle. It is a strongly magnetized steel needle, turning on the center of gravity A B, in a brass frame which is suspended by a thread. Thus the needle has universal motion. The scale is omitted as unnecessary for the present purpose.

323. The dip of the needle does not vary materially at the same place, but differs in different latitudes, increasing as it is carried toward the north, and diminishing as it is carried toward the south. At London, the dip for many years has varied little from 72 degrees. In the latitude of 80 degrees north, the dip, according to the observations of Captain Parry was 88 degrees.

FIG. 274.



Dipping Needle.

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320. How was the dip of the magnetic needle first discovered? 321. In what manner is the dip measured?

324. VARIATION OF THE MAGNET.—Although, in general terms, the magnetic needle is said to point north and south, yet this is very seldom strictly true, there being a variation in its direction, which differs in degree at different times and places. This is called the *variation*, or *declination*, of the magnetic needle.

325. This variation is determined at sea, by observing the different points of the compass at which the sun rises, or sets, and comparing them with the true points of the sun's rising or setting, according to astronomical tables. By such observations it has been ascertained that the magnetic needle is continually declining alternately to the east or west from due north, and that this variation differs in different parts of the world at the same time and at the same place at different times.

326. The annexed table shows at once, the *dip*, or *inclination*, and the *variation* or *declination* of the needle, for a series of years. It was formed from observations made at Brussels, and by it there appears to be a gradual, but constant diminution of the angle, both of *inclination* and *declination*, in Europe.

Month.	Year.	Inclination.	Declination.
October, . .	1827,	68°, 56′, 5″	22°, 28′, 8″
March, . . .	1830,	68°, 52′, 6″	22°, 25′, 3″
March, . .	1832,	68°, 49′, 1″	22°, 19′, 0″
March, . .	1833,	68°, 42′, 8″	22°, 13′, 4″
April, . .	1834,	68°, 38′, 4″	22°, 15′, 2″
March, . . .	1835,	68°, 35′, 0″	22°, 6′, 7″
March, . .	1836,	68°, 32′, 2″	22°, 7′, 6″
March, . . .	1837,	68°, 28′, 8″	22°, 4′, 3″
March, . .	1838,	68°, 26′, 1″	22°, 3′, 7″
March, . . .	1839,	68°, 22′, 4″	21°, 53′, 6″

327. The difference in the declination, which may be of much importance, as on it may depend the safety of ships at sea, is very material in different countries, and at different periods. Thus at present it is about 24° west, at London. At Paris, 22° west. At New York, 5° 25′ west, and at Hartford, about 6° west.

Before 1660, the variation at London, was toward the east, and on that year the needle pointed due north. From that

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323. What circumstance increases or diminishes the dip of the needle? 324. What is meant by the declination of the magnetic needle? 326. What changes does the above table indicate? 327. Why is the difference of declination of importance to ships?

time to the present, it has gained from two to six degrees toward the west every year.

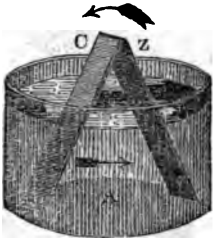
The greatest variation of the magnetic needle, recorded, was that observed by Capt. Cook, which was about 43° west. This was in S. lat. 60°, and E. longitude, 92° 36′.

CHAPTER XV.

ELECTRO-MAGNETISM.

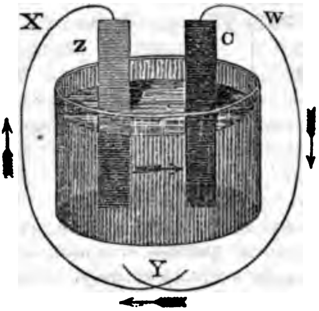
328. *When two metals, one of which is more easily oxydated than the other, are placed in acidulated water, and the two metals are made to touch each other, or a metallic communication is made between them, there is excited an electrical or galvanic current, which passes from the metal most easily oxydated, through the water, to the other metal, and from the other metal through the water around to the first metal again, and so in a perpetual circuit.*

FIG. 275.



Galvanic Current.

FIG. 276.



Galvanic Battery.

329. If we take, for example, one slip of zinc, and another of copper, and place them in a cup of diluted sulphuric acid, *Fig.* 275, their upper ends in contact and above the water, and

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328. What conditions are necessary to excite the galvanic action? From which metal does the galvanism proceed? 329. Describe the circuit by Fig. 275.

their lower ends separated, then there will be constituted a *galvanic circle*, of the simplest form, consisting of three elements, *zinc*, *acid*, *copper*. The galvanic influence being excited by the acid, will pass from the zinc Z, the metal most easily oxydated, through the acid, to the copper C, and from the copper to the zinc again, and so on continually, until one or the other of the elements is destroyed, or ceases to act.

The same effect will be produced, if instead of allowing the metallic plates to come in contact, a communication between them be made by means of wires, as shown by *Fig.* 276. In this case, as well as in the former, the electricity proceeds from the zinc Z, which is the positive side, to the copper C, being conducted by the wires in the direction shown by the arrows.

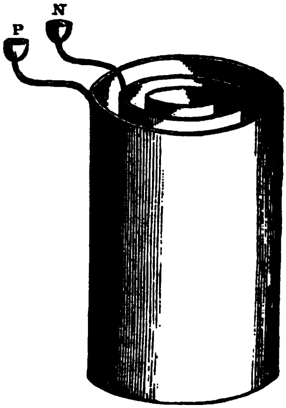
330. The completion of the circuit by means of wires enables us to make experiments on different substances by passing the galvanic influence through them, this being the method employed to exhibit the effects of galvanic batteries, and by which the most intense heat may be produced.

When the two poles of a battery are connected by means of a copper wire of a yard or two in length, the two parts being supported on a table in a north and south direction, for some of the experiments, but in others the direction must be changed as will be seen. This wire, it will be remembered, is called the *uniting wire*.

331. *Theory.*—In theory, the positive electricity is produced by the mutual action of the acid, water, and zinc; the water, in small quantity, being decomposed. If this action is too violent, that is, if the acid is too strong and the hydrogen produced in too large quantity, the electrical current is diminished, or ceases almost entirely.

332. GALVANIC BATTERY.—One of the most convenient forms of a galvanic battery for experiments described in this work is represented by *Fig.* 277. It consists of a cylinder of sheet copper, within which is another

FIG. 277.



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331. How is positive electricity produced ?

of zinc. The zinc has for its bottom a piece of sheep-skin, or bladder, tied on with a string, and is suspended an inch or two from the bottom of the copper cylinder. Or, the whole inner cylinder may be made of leather with a slip of zinc within it. This is done to prevent the fluid which the inner cylinder contains from mixing with that contained between the two; and still, the leather being porous, the water it contains conducts the galvanic influence from one cell to the other, as already stated. The diameter of the outer cup may be five or six inches, and the inner one three or four. The zinc may be suspended by making two holes near the top and tying on a piece of glass tube or a slip of wood. This part has often to be removed and cleaned, by scraping off the black oxyd, which, if it remains, will prevent the action of the battery. The action will be sustained much longer if the zinc is amalgamated by spreading on it a little mercury before it is used, and while the surface is bright.

The cups P N, are the positive and negative poles. They may be made of percussion caps, soldered to the ends of two copper wires; the other ends being connected by soldering, or otherwise, one with the zinc, and the other with the copper, cylinder.

The inner cup is to be filled with water, mixed with about a twentieth part of sulphuric acid, while the cell between the two contains a saturated solution of sulphate of copper, or blue vitriol. In order to keep the solution saturated, especially when casts are to be taken, some of the solid vitriol is to be tied in a rag and suspended in it.

This battery, it will be seen, differs materially from that hereafter to be described under the name of Grove's battery, but for common purposes it is equally useful; is much more readily made, and costs only a tenth as much.

GROVE'S BATTERY.

333. This is the most powerful arrangement, according to its size and cost, which has been proposed, and is that generally used for telegraphic purposes. *Fig.* 278 shows a battery of twelve cups, each of which consists of a cylinder of amalgamated zinc, within which is a cup of unglazed clay; these being placed within an outer cup of glass. To the zinc is attached a conducting arm of the same metal, which reaches to the next series of cups, and at the end of which is attached a thin piece of platina, which dips into the porous cup, as shown by the figure.

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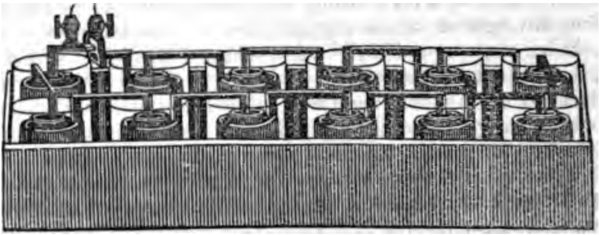
332. Explain Fig. 277, and show the action of the battery. 333. Describe the principle of Grove's battery, Fig. 278.

FIG. 278.

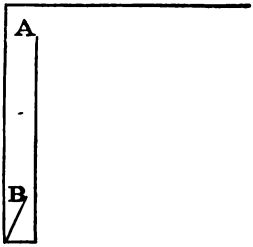


Grove's Twevle-Cup Battery.

The battery is charged, by filling the clay cup with nitric acid, and the space within and around the zinc, which is open at the bottom and side, with sulphuric acid, diluted with 30 parts of water. The action is strong, and requires very little expense.

334. *Tobacco Pipe Battery.*—For telegraphic batteries the vessels are about four inches high, but for common experiments any one may make a miniature battery in the following manner, and at a very trifling expense.

FIG. 279.



Tobacco Pipe Battery.

Procure six toy tumblers, an inch and a half high. Cut from sheet zinc, strips of such size as to form cylinders to go within these tumblers. Cut one end of each strip nearly off, and a quarter of an inch wide, as shown at A, *Fig.* 279, and turn it up so as to make a connecting arm with the next cup. At the end of this arm cut a slit B, into which put a little slip of platina foil, half an inch wide, and an inch long. In this manner the whole can be made without soldering the arm to the cup, which, when amalgamated, will drop off.

Next take six tobacco pipes, and breaking off the stems, stop the orifices of the bowls with sealing-wax, and the elements of your little battery is finished.

Now take a little mercury in a bowl, and touching the zinc

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334. How is the tobacco pipe battery made?

cylinders to it, a little will adhere to the metal, and may be spread over its surface with a wisp of cotton. The action is thus much increased.

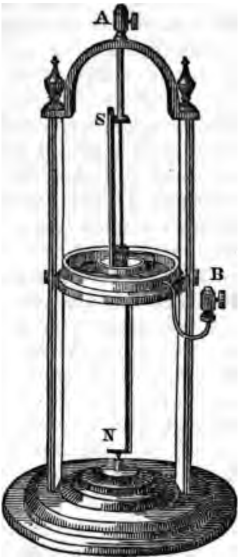
335. Lastly, put the bowls within the zinc cylinders, and these into the tumblers, and then fill the bowls with nitric acid, and the tumblers with sulphuric acid diluted with 30 parts of water, fixing the arms so that the platina will dip into the bowls, and the action will commence instantly.

With this little battery, which any one of ordinary ingenuity can make, all the common experiment with a galvanic battery may be performed.

336. *Circular Motion of Electro-Magnetism.*—In consequence of the circular magnetic currents which seem to emanate from the regular influence of the battery, the fluid may be made to act so as to produce a continued rotation of the conducting wire, or the magnet.

Magnet Revolving Around the Conducting Wire.—The arrangement shown by *Fig.* 280, and which causes the magnet to revolve around the conducting wire, consists of the magnet N S, having an angular bend in the middle, where it becomes horizontal, while the extremities are vertical. To the north pole, or lower end of the magnet N, is attached a piece of brass, at a right-angle with the magnet, which has a little projection, forming a pivot, which rests in an agate cup, fixed to the stand. A wire loop attached to the upper pole of the magnet S, encircles the conducting wire, and thus keeps the magnet in its place. The galvanic current is conveyed by this wire, the lower end of which dips into a little cup of mercury on the horizontal portion of the magnet.

FIG. 280.



Revolving Magnet.

337. The wire has a brass cup at A, containing mercury, and into which the pole of the battery is inserted. From this cup

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335. With what is this battery charged?

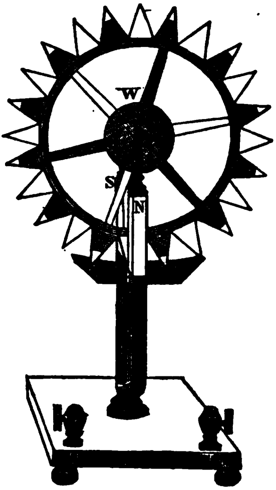
projects a bent wire, as seen in the figure, the end of which dips into a circular cistern of mercury, contained in a brass cup, and through which the magnet revolves. A wire passes through the side of the cistern to the mercury, and terminates in the screw-cup B, into which the other pole of the battery is placed.

Now on making the connection, the current flows down by the side of the upper pole of the magnet to the middle, and then takes the direction of the cup B, so as not to act on the lower pole, the galvanic force being between the mercury in the cistern and the bent wire, and by the attraction of which the magnet revolves rapidly around the conducting wire. On changing the poles the rotation will be in a contrary direction.

338. Revolving Spur-Wheel.—Many curious experiments are made by combining the action of electricity with that of magnetism. Such a combination is shown by *Fig.* 281 where W is a copper wheel cut into points, and made to revolve between the legs of a U magnet fixed in an upright position. The axis of the wheel is supported by strips of brass fastened to the magnetic poles N and S. The trough T may be of brass or wood, and is placed between the bifurcation of the magnet. This contains a little mercury, into which the teeth of the wheel just dip, as they revolve.

339. On the platform or stand, to which the magnet is fastened, are two screw-cups to which the opposite poles of the battery are fastened. One of these cups is connected with the magnet, and through that, with the axis of the wheel, and the other with the mercury in the trough. Now on making the connection between the poles of the battery, the wheel begins to move, in consequence of the attraction between the points of the wheel and the mercury, and if the current is strong the wheel turns with great velocity, snapping and striking fire as the points

FIG. 281.



Revolving Wheel.

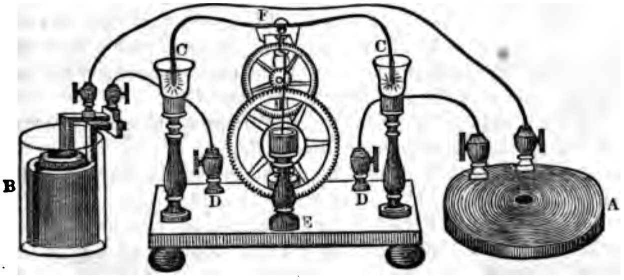
approach the fluid metal. The points of the wheel should be amalgamated to make the experiment succeed well.

CLOCK-WORK VIBRATING WIRE.

340. This is a curious and singular arrangement, and will quite astonish those who are not conversant with motions communicated by galvanic influence.

The cut, *Fig.* 282, shows a connection between the *spiral ribbon*, A, and the single Grove's battery, B, by means of a copper wire. The bent wire C C, suspended in the middle, is set in motion by a spring below the milled-head F, and is made to vibrate rapidly by clock-work, the ends of the wire dipping alternately in the glass cups C C, containing mercury. The spring is wound up by turning the milled-head.

FIG. 282.



Clock-work Vibrating Wire.

The glass cups are open at the bottom to allow the mercury to come in contact with the brass pillars on which they stand.

Both of these pillars are connected with one of the screw-cups D D, while the other cup is connected with the middle brass pillar E, on which is a brass cup of mercury. From the latter cup ascends a vertical wire, attached to the vibrating wire, as the figure shows.

341. Such a quantity of mercury is put into the brass cup as to keep the end of the vertical wire covered, and enough into the glass cups C C, to allow one end of the vibrating wire to leave the mercury in the cup, before the other end dips into that metal.

342. The *spiral ribbon* is made by cutting strips of sheet copper, an inch wide, into lengths, and soldering them together.

Then having covered the whole with cotton cloth, and rolled it into a spiral, like a watch-spring, the article in question is formed. At each end, the ribbon being sometimes 100 feet long, there is fixed a screw-cup to contain mercury for the poles of the battery. In the above, one end is connected with the battery, and the other with the screw-cup D, and so to E, on the platform.

The current must be transmitted through the two instruments in succession, by connecting one of the screw-cups with one of those attached to the spiral wire, and the other with the pole of the battery; the remaining cup on the spiral being made to communicate with the other pole of the battery.

343. *Action.*—On making the connection with the spiral, as shown, and turning the milled-head to put the vibrating wire in motion, a brilliant spark will be seen, and a loud snap heard, at the alternate rupture of the contact between the ends of the wire and the mercury in the cups C C.

With a battery of a few pairs of large sized plates, the size of the spark will be greatly increased.

A strong shock may also be given, especially when the mercury in the cups C C are covered with a little oil.

[The author is indebted for the above, as well as for several other cuts of the same kind, to Davis's "Manual of Magnetism," Boston, 1850.

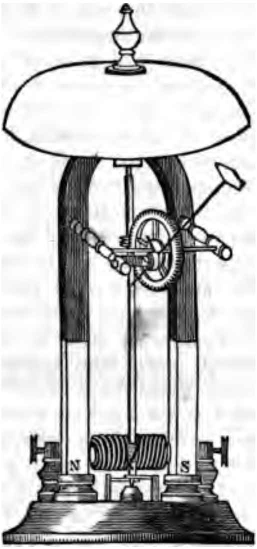
This work contains the most complete and extensive set of figures, and their descriptions, on the subjects of Magnetism and Electricity, ever published in this country. Price $1,00. The number of figures, 184.]

REVOLVING BELL ENGINE.

344. This curious arrangement is the invention of Mr. Page. It consists of a U shaped magnet, the north and south poles, N S, being fixed in the base board. Between these is a small electro-magnet of iron, surrounded with insulated copper wire. This is fixed to a revolving axis, or wire, the upper end of which is confined in the bend of the large magnet, and the lower one running in a support below the electro-magnet. On the outside of the U magnet are the connecting screws for the opposite poles of the battery, by which the machine is operated. On the axis, and connected with the notches of the wheel, is an endless screw, and with this is connected the hammer, which strikes the bell, seen as a crown on the figure.

345. *Action.*—The operation, or motion, of this curious little

FIG. 283.



Bell Engine.

engine, depends on the alternate attraction and repulson of the poles of the U magnet, and those of the small electro-magnet between them. The magnetism of the latter depends on the influence of the battery with which it is connected, and therefore ceases when this connection is broken. The revolution is therefore caused by the mutual repulsion, and then the mutual attraction between the two opposite poles of the two magnets, as the connection is broken and the poles of the electro-magnet are reversed.

The hammer is made to strike by a pin on the wheel, moved by the endless screw, and which presses back the handle until it is released, when a spiral spring on the handle impels it against the bell.

346. If the wheel has 100 teeth, as in the cut, the electro-magnet must revolve 100 times in order to produce one revolution of the wheel, and consequently one stroke on the bell. The velocity of the electro-magnet in this machine, as shown by the striking of the hammer, is sometimes equal to 6000 revolutions in a minute.

347. VIBRATION OF A WIRE.—A conducting copper wire W, *Fig.* 284, is suspended by a loop from a hook of the same metal, which passes through the arm of metal or wood, as seen in the cut. The upper end of the hook terminates in the cup P to contain mercury. The lower end of the copper wire just touches the mercury, Q, contained in a little trough about an inch long, formed in the wood on which the horseshoe magnet, M, is laid, the mercury being equally distant from the two poles.

The cup, N, has a stem of wire which passes through the wood of the platform into the mercury, this end of the wire being tinned, or amalgamated, so as to form a perfect contact.

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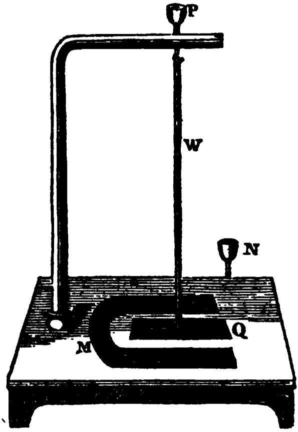
347. Explain Fig. 284, and describe the course of the electric fluid from one cup to the other. How must the points of the vibrating wire be adjusted in order to act?

FIG. 284.



Vibration of a Wire.

348. Having thus prepared the apparatus, put a little mercury into the cups P and N, and then form the galvanic circuit by placing the poles of the battery in the two cups, and if every thing is as it should be, the wire will begin to vibrate, being thrown with considerable force either toward M or Q, according to the position of the magnetic poles, or the direction of the current, as already explained. In either case it is thrown out of the mercury, and the galvanic circuit being thus broken, the effect ceases until the wire falls back again by its own weight, and touches the mercury, when the current being again perfected, the same influence is repeated, and the wire is again thrown away from the mercury, and thus the vibratory motion becomes constant.

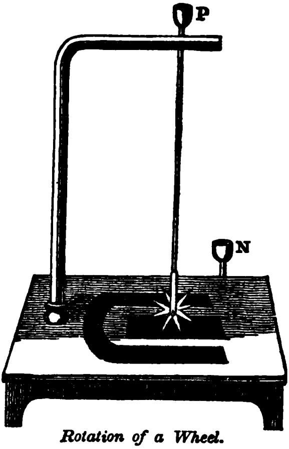
This forms an easy and beautiful electro-magnetic experiment, and may be made by any one of common ingenuity, who possesses a galvanic battery, even of small power, and a good magnet.

The platform may be nothing more than a piece of pine board, eight inches long and six wide, with two sticks of the same wood, forming a standard and arm for suspending the vibrating wire. The cups may be made of percussion caps, exploded, and soldered to the ends of pieces of copper bell wire.

The wire must be nicely adjusted with respect to the mercury, for if it strikes too deep or is too far from the surface, no vibrations will take place. It ought to come so near the mercury as to produce a spark of electrical fire, as it passes the surface, at every vibration, in which case it may be known that the whole apparatus is well arranged. The vibrating wire must be pointed and amalgamated, and may be of any length, from a few inches to a foot or two.

349. Rotation of a Wheel, *similar to, but more simple, than Fig.* 281. The same force which throws the wire away from

FIG. 285.



Rotation of a Wheel.

the mercury, will cause the rotation of a spur-wheel. For this purpose the conducting wire, instead of being suspended, as in the former experiment, must be fixed firmly to the arm, as shown by *Fig.* 285. A support for the axis of the wheel may be made by soldering a short piece to the side of the conducting wire, so as to make the form of a fork, the lower end of which must be flattened with a hammer, and pierced with fine orifices, to receive the ends of the axis.

The apparatus for a revolving-wheel is, in every respect, like that already described for the vibrating wire, except in that above noticed, the wheel may be made of brass or copper, but must be thin and light, and so suspended as to move freely and easily The points of the notches must be amalgamated, which is done in a few minutes, by placing the wheel on a flat surface, and rubbing them with mercury by means of a cork. A little diluted acid from the galvanic battery will facilitate the process. The wheel may be from half an inch to several inches in diameter. A cent hammered thin, which may be done by heating it two or three times during the process, and then made perfectly round, and its diameter cut into notches with a file, will answer every purpose.

This affords a striking and novel experiment; for when every thing is properly adjusted, the wheel instantly begins to revolve on touching with one of the wires of the battery the mercury in the cup P, the other pole being in N.

When the poles of the magnet, or those of the battery, are changed, the wheel instantly revolves in a contrary direction from what it did before.

It is, however, not absolutely necessary to divide the wheel into notches, or rays, in order to make it revolve, though the

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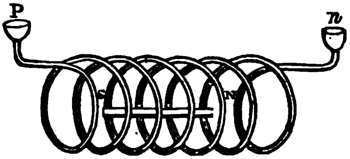
349. Explain Fig. 285. In what manner may the points of the spur-wheel be amalgamated? If the motion of the fluid is changed, what effect does it have on the wheel?

motion is more rapid, and the experiment succeeds much better by doing so.

350. ELECTRO-MAGNETIC INDUCTION.—*Experiment proves that the passage of the galvanic current through a copper wire renders iron magnetic when in the vicinity of the current. This is called magnetic induction.*

FIG. 286.



Electrical Helix.

The apparatus for this purpose is represented by *Fig.* 286, and consists of a copper wire coiled, by winding it around a piece of wood. The turns of the wire should be close together for actual experiment, they being parted in the figure to show the place of the iron to be magnetized. The best method is, to place the coiled wire, which is called an *electrical helix*, in a glass tube, the two ends of the wire, of course, projecting. Then placing the body to be magnetized within the folds, send the galvanic influence through the whole by placing the poles of the battery in the cups.

351. Steel thus becomes permanently magnetic, the poles, however, changing as often as the fluid is sent through it in a contrary direction. A piece of watch-spring placed in the helix, and then suspended, will exhibit polarity, but if its position be reversed in the helix, and the current again sent through it, the north pole will become south. If one blade of a knife be put into one end of the helix, it will repel the north pole of a magnetic needle, and attract the south; and if the other blade be placed in the opposite end of the helix, it will attract the north pole, and repel the south, of the needle.

352. TEMPORARY MAGNETS.—*Temporary magnets, of almost any power, may be made by winding a thick piece of soft iron with many coils of insulated copper wire, and passing the galvanic influence through it.*

The best form of a magnet for this purpose is that of a horseshoe, and which may be made in a few minutes by heating and bending a piece of cylinder iron, an inch or two in diameter, into this form.

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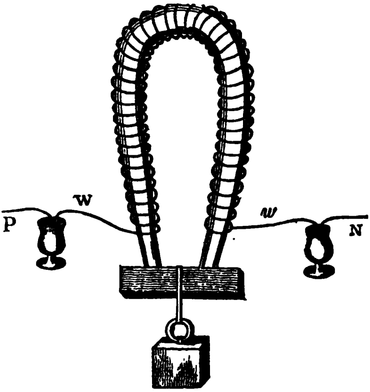
350. What is meant by magnetic induction? Explain Fig. 286. What is the figure called? 351. Does any substance become permanently magnetic by the electrical helix? How may the poles of a magnet be changed by the helix? 352. How may temporary magnets be made?

The copper wire (bell wire) may be insulated by winding it with cotton thread. If this can not be procured, common bonnet wire will do, though it makes less powerful magnets than copper.

353. The coils of wire may begin near one pole of the magnet and terminate near the other, as represented by *Fig.* 287, or the wire may consist of shorter pieces wound over each other, on any part of the magnet. In either case, the ends of the wire, where several pieces are used, must be soldered to two strips of tinned sheet copper, for the combined positive and negative poles of the wires. To form the magnet, these pieces of copper are made to communicate with the poles of the battery, by means of cups containing mercury, as shown in the figure, or by any other method.

FIG. 287.



Temporary Magnet.

354. The effect is surprising, for on completing the circuit with a piece of iron an inch in diameter, in the proper form, and properly wound, a man will find it difficult to pull off the armature from the poles; but on displacing one of the galvanic poles, the attraction ceases instantly, and the man, if not careful, will fall backward, taking the armature with him. Magnets have been constructed in this manner, which would suspend ten thousand pounds.

THERMO-ELECTRICITY.

355. This means electricity by heat, and its principles will be understood, when it is stated that if any two metals of different kinds be joined together and then heated, a current of electricity will pass from one to the other. Thus, if two wires of a few inches in length, German-silver and brass, have their ends soldered together, and the junction heated with an alcohol

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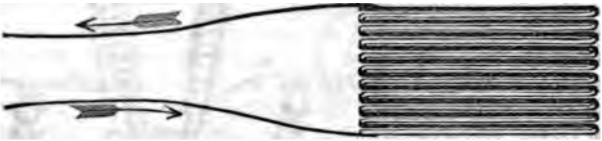
353. For what purpose are the ends of the wires to be soldered to pieces of copper? 355. What is meant by thermo-electricity?

lamp, or by other means, a current of electricity will flow from the silver to the brass, which may be detected by the galvanometer, or by the common electrical needle.

356. *Composition of German-silver.*—As this alloy is cheap, and is much used for electrical purposes, we give its proportions. In 100 parts, it consists of copper 50, zinc 30, and nickel 20. This alloy is a positive electric to all other metals except bismuth, to which it is negative.

FIG. 288.



Thermo-Electricity.

Writers give a great variety of combinations of different metals, with the amount of electrical influence indicated by each. Among these, that shown by *Fig.* 288, is among the most easily constructed and most powerful. It consists of ten strips of German-silver, and as many of brass, rolled thin and laid on each other with their alternate ends soldered together. Strips of pasteboard are placed between the adjacent metals, so that they touch only at the ends where they are soldered. Now by heating the end opposite the poles with a spirit lamp, and bringing the poles in contact, an electrical current will flow from one side or pole, to the other, in the direction of the arrows.

ELECTROTYPE.

357. The art of covering the base metals, as copper, and the alloys of zinc, tin, &c., with gold and silver, as also of copying medals, by means of the electrical current, is called *electrotype* or *voltatype.*

This new art is founded on the simple fact, that when the galvanic influence is passed through a metallic solution, under certain conditions, decomposition takes place, and the metal is deposited in its pure form on the negative pole of the battery.

The theory by which this effect is explained is, that the

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356. Explain by Fig. 288, how thermo-electricity is developed? 357. What is electrotype? On what fact is it said this art is founded? On which pole is the metal deposited? What is the theory by which this effect is explained?

hydrogen evolved by the action of the acid on the positive pole of the battery combines with the oxygen of the dissolved metal forming water, while the metal itself thus set free, is deposited at the negative side of the battery.

Many of the base metals, as copper, the alloys of zinc, and tin, may by such means be covered with gold, or silver, and thus a cheap and easy method of gilding and plating is effected.

This art, now only a few years old, has excited great interest, not only among men of science, but among mechanics, so that in England many hundreds, and perhaps thousands of hands are already employed in silvering, gilding, and coppering, taking impressions of medals and of copperplates, for printing, and of performing such other work as the art is capable of. Volumes have been written to explain the different processes to which this art is applicable, and considering its recent discovery and the variety of uses to which it is already applied, no doubt can exist that it will finally become of great importance to the world.

In this short treatise we can only introduce the pupil to the subject, by describing a few of the most simple processes of the art in question, and this we hope to do in so plain a manner, that any one of common ingenuity can gild, silver, or copper, and take impressions of medals at his leisure.

358. Copying of Medals.—This new art has been applied very extensively in the copying of ancient coins and medals, which it does in the utmost perfection, giving every letter, and feature, and even an accidental scratch, exactly like the original. When the coin is a *cameo*, the figures or letters being raised, it is obvious that if the metal be cast directly upon it, the medal will be reversed, that is, the figures will be indented, and the copy will be an *intaglio* instead of a cameo. To remedy this, a cast, or impression must first be taken of the medal, on which the electrotype process is to act, when the copy will, in all respects, imitate the original.

There is a variety of ways of making such casts, according to the substance used for the purpose. We shall only mention plaster of Paris, wax, and fusible metal.

359. Plaster Casts.—When plaster is used, it must be, what is termed baked, that is, heated, so as to deprive it of all moisture. This is the preparation of which stereotype casts are made. The dry powder being mixed with water to the consistence of cream, is placed on the medal with a knife to the thickness of a quarter or half an inch, according to its size. In a few minutes the plaster *sets*, as it is termed, or becomes hard.

To insure its easy detachment, the medal is rubbed over with a little oil.

The cast thus formed is first to be coated with boiled linseed oil, and then its face covered with fine pulverized black lead, taking care that the indented parts are not filled, nor the raised parts left naked. The lead answers the purpose of a metallic surface, on which the copper is deposited by the galvanic current. This is a curious and very convenient discovery, since wood cuts, engraved stones, and copies in sealing-wax, can thus be copied.

To insure contact between the black lead on the face of the cast and the wire-conductor, the cast is to be pierced with an awl, on one of its edges, and the sharp point of the wire passed to the face, taking care, after this is done, to rub on more lead, so that it shall touch the point of the wire, and thus communicate with the whole face of the medal.

360. Wax Casts.—To copy medallions of plaster of Paris, place the cast in warm water, so that the whole may be saturated with the water, but keeping the face above it. When the cast has become warm and moist, remove, and having put a slip of paper around its rim, immediately pour into the cup thus formed bees wax, ready melted for this purpose. In this way copies may be taken, not only from plaster casts, but from those of other substances.

To render the surface of the wax a conductor of electricity, it is to be covered with black lead in the manner directed for plaster casts. This is put on with a soft brush, until it becomes black and shining.

The electrical conductor is now to be heated and pressed upon the edge of the wax, taking care that a little of its surface is left naked, on, and around which the black lead is again to be rubbed, to insure contact with the whole surface.

Both of the above preparations require considerable ingenuity and attention, in order to make them succeed in receiving the copper. If the black lead does not communicate with the pole, and does not entirely cover the surface, or if it happens to be a poor quality, which is common, the process will not succeed; but patience, and repeated trials, with attention to the above descriptions, will insure final success.

361. Fusible Metal Casts.—This alloy is composed of 8 parts of bismuth, 5 of lead, and 3 of tin, melted together. It melts at about the heat of boiling water, and hence may be used in taking casts from engraved stones, coins, or such other substances as a small degree of heat will not injure.

To take a cast with this alloy, surround the edge of the medal to be copied, with a slip of paper, by means of paste, so as to form a shallow cup, the medal being the bottom. Then having melted the alloy in a spoon, over an alcohol lamp, pour it in, giving it a sudden blow on the table, or a shake, in order to detach any air, which may adhere to the medal. In a minute or two it will be cool, and ready for the process.

Another method is, to attach the medal to a stick, with sealing-wax, and having poured a proper quantity of the fused alloy on a smooth board, and drawn the edge of a card over it, to take off the dross, place the medal on it, and with a steady hand let it remain until the cast cools.

Next, having the end of the copper wire for the zinc pole clean, heat it over a lamp, and touch the edge of the cast therewith, so that they shall adhere, and the cast will now be ready for the galvanic current.

To those who have had no experience in the electrotype art, this is much the best, and most easy method of taking copies, as it is not liable to failure like those requiring the surfaces of the molds to be black leaded, as above described.

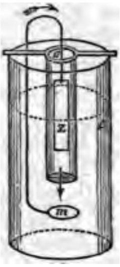
362. Galvanic Arrangement.—Having prepared the molds, as above directed, these are next to be placed in a solution of the sulphate of copper, (blue vitriol) and subjected to the electrical current. For this purpose only a very simple battery is required, especially where the object is merely a matter of curiosity.

For small experiments, a glass jar holding a pint, or a pitcher, or even a tumbler will answer, to hold the solution. Provide also a cylinder of glass two inches in diameter, and stop the bottom with some moist plaster of Paris, or instead thereof, tie around it a piece of bladder, or thin leather, or the whole cylinder may be made of leather, with the edges sewed nicely together, and stopped with a cork, so that it will not leak. The object of this part of the arrangement is, to keep the dilute sulphuric acid which this contains, from mixing with the solution of sulphate of copper, which surrounds it, still having the texture of this vessel so spongy as to allow the galvanic current to pass through the moisture which it absorbs, water being a good conductor of electricity.

Provide also a piece of zinc in form of a bar, or cylinder, or slip, of such size as to pass freely into the above described cylinder.

Having now the materials, the arrangement will readily be understood by *Fig.* 289, where *c* is the vessel containing the solution of sulphate of copper; *a*, the cylinder of leather, or glass; *z*, the zinc, to which a piece of copper wire is fastened, and at the other end of which, is the cast *m*, to be copied. The proportions for the vessel, *a*, are about 1 part sulphuric acid to 16 of water by measure. The solution of copper for *c*, may be in the proportions of 2 ounces of the salt to 4 ounces of water. The voltaic current passes from the positive zinc to the negative amalgam cast, where the pure copper is deposited.

FIG. 289.



In order to keep the solution saturated, a little sulphate of copper is tied in a rag, and suspended in the solution. In 24 or 36 hours, the copper, (if all is right.) will be sufficiently thick on the cast, the back and edges of which should be covered with varnish to prevent its deposition except on the face.

If the copper covers the edges, a file or knife will remove it, when by inserting the edge of the knife between the two metals, the copy will be separated, and will be found an exact copy of the original.

If the acid in the inner cylinder is too strong, the process is often too vigorous, and the deposition, instead of being a film of solid copper on the cast, will be in the form of small grains on the lower end of the wire. The weakest power consistent with precipitation should therefore be applied.

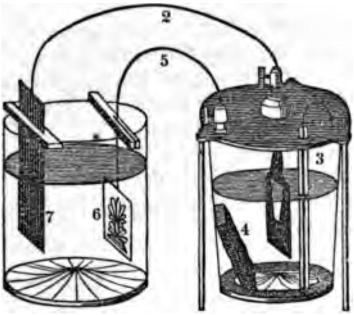
SMEE'S BATTERY.

363. This is an improved method of copying casts, or molds, in copper. It consists of two glass vessels, each holding a pint, or less, one of which holds the battery, and the other the depositing apparatus. These arrangements will be understood by *Fig.* 290, of which 1 is a little mercury on the bottom of the vessel, containing the battery. Just above this is a piece of platinum foil, suspended in the center. A piece of zinc, 4, rests against the side of the vessel. A curved copper wire, 3, descends through the liquid, insulated by a glass tube. This wire, by the mercury, connects the zinc plate with the metallic cup on the top of the jar, and by the wire, 2, with the other jar. The wire, 5, descends from the screw-cup into the depositing cell, to the end of which the cast, 6, is suspended. The plate 7, is a piece of copper suspended in the solution of sulphate

of copper, in order to keep it always of the same strength, a portion being dissolved, while another portion is deposited on the cast.

The liquid in the battery is composed of one part sulphuric acid, and 20 or 30 of water. That in the depositing side, is composed of 2 ounces of sulphate of copper, 1 ounce of sulphuric acid, and 15 ounces of water.

FIG. 290.



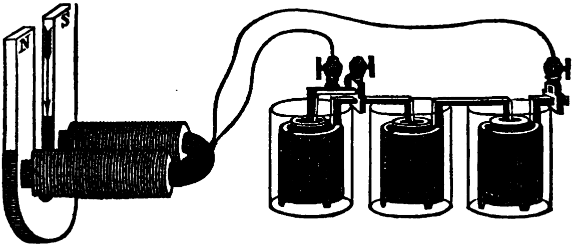
Smee's Battery.

The general directions for obtaining casts have been given above, and need not be repeated.

MAGNETISM BY ELECTRO-MAGNETISM.

364. The apparatus, *Fig.* 291, is designed to communicate strong and permanent magnetism to steel. It consists of a small Smee's battery, with its opposite poles connected with the horizontal U magnet, which is closely wound with insulated copper wire. Of course the wires convey the electrical influence from the positive to the negative sides of the battery.

FIG. 291.



Magnetism by Electro-Magnetism.

The cut represents a U magnet in the process of being magnetized. This is done by drawing it from the bend, across the electro-magnet to the poles, and repeating this on both its sides, taking care to do it in the same direction. A steel bar may be magnetized by the same process, or, if a short one, by applying it as an armature to the poles of the electro-magnet; the north pole becoming the south pole of the new magnet.

365. To remove the magnetism of a steel magnet of the U form, it is only required to reverse the process, that is, to place one of its poles on each pole of the electro-magnet, and draw it over them, in the direction contrary to the indication of the arrow seen in the figure.

In the vertical magnet, the letters N S, indicate its north and south poles.

ELECTRO-GILDING.

366. *Gilding without a Battery.*—After the solution is prepared, the process of electrotype-gilding is quite simple, and may be performed by any one of common ingenuity.

The solution for this purpose is cyanide of gold dissolved in pure water. This is prepared by dissolving the metal in aqua-regia, composed of one part nitric, and two of muriatic acid. Ten or fifteen grains of gold, to an ounce and a half of the aqua-regia may be the proportions. The acid being evaporated, the salt which is called the chloride of gold is dissolved in a solution, made by mixing an ounce of the cyanuret of potash with a pint of pure water. The cyanuret of potash is decomposed and a cyanide of gold remains in solution. About 20 grains of the chloride of gold is a proper quantity for a pint of the solution. The cyanuret of potash, and the chloride, or oxyd of gold, may be bought at the apothecaries.

Having prepared the solution, the most simple method of gilding is to pour a quantity of it into a glass jar, or a tumbler, and place in it the silver, copper, or German-silver to be gilded, in contact with a piece of bright zinc, and the process will immediately begin. No other battery, except that formed by the zinc, and metal which receives the gold, is required. The zinc at the point of contact must be bright and well fastened to the other metal by a string or otherwise. The process will be hastened by warmth, which may be applied by placing the jar and its contents in a vessel of warm water. So far as the author knows, this simple process originated with himself, and answers admirably as an experiment in the electrotype art. The gold, however, is apt to settle upon the zinc, but which may be prevented by a little shellac varnish rubbed on it, except at the point of contact. The handles of scissors, silver spectacles, pencils, &c., may be handsomely gilt by this process.

367. GILDING WITH A BATTERY.—If the operator desires to extend his experiments in the art of electro-gilding, a small battery must be employed, of which there are many varieties. The best for more extensive operations, is that composed of platinized silver, and amalgamated zinc.

For this purpose the platina is first dissolved in aqua-regia, in proportion of 10 grains to the ounce, and then precipitated on the silver. The silver is in sheets, such as is used for plating, no thicker than thin writing paper. This may be obtained of the silver-platers, and being well cleaned, is ready for the process.

These plates being covered with platina, are insoluble in the acid employed, and hence they will last many years. The amalgamated plates are also durable, and do not require cleaning.

368. These platinized sheets are confined between two plates of amalgamated zinc. The process of amalgamation consists in rubbing mercury, with a little mass of cotton wool held in the fingers, on the clean zinc. These plates may be fixed half an inch apart by means of little pieces of wood, with the sheets between them, but not touching each other. The plates, having a metallic connection, form the positive side of the battery, while a copper wire soldered to the silver sheet makes the negative side. The dimensions of these plates may be four or five inches long, and three or four wide.

For experimental purposes, however, a less expensive battery may be used, that represented by *Fig.* 289, made of copper and zinc, being sufficient.

To gild by means of a battery, place the solution, made as above described, in a glass vessel, and connect the article to be gilded with the pole coming from the zinc side of the battery, letting the other wire, which should be tipped with a little piece of gold, dip into the solution. The gilding process will immediately begin, and in three or four hours a good coat of gold will be deposited on the article immersed.

To keep the solution quite pure, the tips of the poles where they dip into the fluid should be of gold. If they are of copper, a portion of the metal will be dissolved and injure the result.

ELECTRO-PLATING.

369. The process of silvering copper, or the alloys of the metals, such as German-silver, is done on the same principle as that described for gilding, but there seems to be more difficulty in making the process succeed to the satisfaction of the artist than there is in depositing gold.

The following is the method employed by Mr. Sumner Smith, of this city, the most experienced electrotype artist within our acquaintance. It will succeed perfectly in the hands of those who will follow the directions.

Make a solution of cyanuret of potash in pure water, in the proportion of an ounce to a pint. Having placed it in a glass vessel, prepare the battery for action as usual. Then attach to the pole of the silver, or copper side of the battery, a thin plate of silver, and immerse this in the cyanuret solution. The pole from the zinc side being now dipped into the fluid, the electro-chemical action on the silver plate instantly begins, and a rapid decomposition of the metal is effected, and in a short time the solution will be saturated with the silver, as will be indicated by the deposition of the metal on the end of the copper pole coming from the zinc side of the battery. The solution is now ready for use, but the remains of the silver, still undissolved, must not be removed before immersing the articles to be plated, since the solution is thus kept saturated.

This solution is much better than that prepared by dissolving the silver separately in an acid, and then re-dissolving in the cyanuret of potash as is usually done, for in the latter case the silver is apt to be deposited on German-silver, brass, iron, and other metals, without the galvanic action, in which case it does not adhere well, whereas the solution made as above directed is not liable to this imperfection.

During the preparation of the fluid, only a very small copper wire should be employed on the zinc side of the battery.

The articles to be plated must be well cleaned before immersion. To effect this, dip them into dilute sulphuric acid for a few minutes, then rub them with sand or whiting, and rinse in pure water.

Now having exchanged the small copper pole of the zinc side of the battery, for a larger one of the same metal, tipped with silver, connect the article to be plated with this, the other pole with the silver plate attached being still immersed in the solution.

The process must now be watched, and the silver attached to the copper side raised nearly out of the fluid, in case bubbles of hydrogen are observed to rise from the pole on the other side, or the articles attached to it. The greater the surface of silver in the fluid, the more energetic will be the action, short of the evolution of hydrogen from the other pole, but when this is observed, the decomposing silver must be raised so far out of the fluid as to stop its evolution.

By this method a thick and durable coat of silver may be placed on old copper tea-pots, candlesticks, or other vessels of this sort, where the silvering has been worn off by long use.

PHOTOGRAPHY.

370. The word *photography*, means written, or delineated by light, and is descriptive of the manner in which the pictures, or designs we are about to describe, are taken. The principle on which this art is founded is quite simple, and will be readily understood by those who have made chemical experiments, and especially with nitrate of silver, of which the common marking ink is made. This is merely a solution of some salt of silver, the nature of which is, to grow dark on exposure to light, but remains colorless when kept in a perfectly dark place.

Now if a sheet of white paper be imbued with a solution of this salt, and then with the hand placed upon it, exposed to the light, there will be a figure of the hand left on the paper, in white, the ground being black. The reason of this, from what we have already said, is obvious; that portion of the paper which is protected by the hand remains white, while that which is exposed to the light turns black.

The photographic art consists in first covering common writing paper with the salt of silver, then taking the picture by means of the camera obscura, and afterward applying some solution which prevents the ground from changing its color by exposure to the light.

The chief difficulty lies in perfecting the latter part of the process, and for this purpose, as well as with respect to the particular salt of silver to be used, and the way of applying it, a great variety of methods have been devised.

Nitrated Paper.—The most simple kind of photographic paper is made by dissolving one ounce of the crystalized nitrate of silver in four ounces of pure water, and applying it to the paper by means of a soft brush.

For this purpose the paper must be fastened to a piece of board with pins at each corner. In putting on the solution care must be taken not to touch the same part twice with the brush, for if it is not spread equally, the sheet will grow darker in some parts than in others.

The paper being dried by the fire in a darkened room, is then ready to receive the impression in the camera obscura. It is then soaked for a few minutes in warm water, by which the nitrate around the picture is washed away, and the r will remain white. This is to be very carefully done, with the paper pinned to the board, otherwise it will be torn and spoiled.

The nitrated paper, after being dried, and before the picture is taken, will become much more sensitive to the light if it is soaked in a solution of isinglass, or rubbed over with the white of an egg. It is better, however, to do this before the nitrate of silver is put on.

The paper prepared in this manner is not sufficiently sensitive to be changed by diffused light, and consequently requires the rays of the sun in order to produce the photographic effect.

371. *Murio-nitrated Paper.*—Another method of preparing the paper is first to moisten it with a solution of muriate of soda, (common salt,) and then apply the nitrate of silver.

For this experiment, dissolve fifty grains of the salt in an ounce of water, and soak the paper in the solution. For this purpose it must be pinned to a board as formerly directed. After being pressed with a linen cloth or with blotting paper, and thus dried, it is then twice washed with a solution made by dissolving one hundred and twenty grains of crystalized nitrate of silver in an ounce of rain water. It must be dried by the fire of a darkened room between each washing.

This paper is very sensitive, the color changing by small degrees of light. It must, therefore, be kept in the dark to the moment of using.

A great variety of other methods of making photographic paper are described in treatises on the art, and to those we must refer the student who is inquisitive on such subjects.

372. *Camera Obscura.*—An instrument of this kind of the ordinary construction, has already been figured and described, but a more simple and less expensive apparatus will answer for experiments in the art under consideration.

Any one who lives near a joiner's shop, and who is desirous of making photographic experiments, can make his own camera obscura.

For this purpose, two boxes, each a foot long and eight or ten inches square, the one sliding within the other, is all that is required for the body of the camera. In one of the boxes is placed the lens, an inch and a half, or two inches in diameter, having a focal distance of 12 or 15 inches. The boxes are to be painted black on the inside to prevent the diffusion of light. This may be done with spirits of turpentine and lampblack.

The paper is fastened to a piece of thin board, which is to be attached to the inner, or sliding box. Through the upper, and back part of the box, there is a small hole through which the operator can see to adjust the paper in the focus of the lens, by sliding the box in, or out, as the case requires.

Taking care to turn the sensitive side of the paper toward the lens, place it so that the best defined images of things fall upon its surface. In this position it must remain a sufficient length of time to receive the impression.

The time required for this is of course quite variable, depending on the intensity of the light and the sensibility of the paper. It may, however, be stated, as a general guide, that highly sensitive paper, in the sunshine of a summer morning, requires about thirty minutes for the impression to be complete. If the light is less intense and the paper less perfect, it ought to remain an hour in the camera.

Fixing the Picture.—When the paper is made sensitive by the murio-nitrate of silver, as in the last process described, the picture is fixed, and the other parts of the paper rendered insensible by a solution of hyposulphate of soda. The solution is made by dissolving an ounce of the salt in a quart of water. A portion of this being placed in a shallow dish, the pictures are introduced one at a time, and allowed to remain two or three minutes. They are then washed in pure water, and then may be dried by exposure to the sun, which now effects no change in the color.

TALBOTYPE.

373. The branch of photography, called *Talbotype*, has been so named in honor of Fox Talbot, Esq., who has invented and introduced many improvements in this curious art.

Instantaneous Images.—Ever since the discovery of Daguerre, it has been an object among artists to discover some process by which a picture could be taken instantaneously, and it appears by the following, that this feat has been executed by Mr. Talbot. The mechanical portion of the process he thus describes.

A printed paper was fixed upon a circular disc, which was made to revolve on its axis as rapidly as possible. When it had attained its greatest velocity, an electric battery was discharged in front of the disc, lighting it up with a momentary flash. A camera, containing a very sensitive plate of glass, had been placed in a suitable position, and on opening this after the discharge, an image was found of a portion of the words printed on the paper. They were perfectly well defined, and wholly unaffected by the motion of the disc. The mode of preparing this sensitive plate is too long and complicated for description in this work.

DAGUERREOTYPE.

374. This branch of photography was the invention of M. Daguerre, an ingenious French artist, and is entirely independent of the art of taking impressions on paper, as above described. In that the pictures are reversed, in this they are in the natural position, and instead of paper, the picture is on silver.

As an art, this is one of the most curious and wonderful discoveries of the present age; for when we witness the variety of means necessary to the result, it would appear equally improbable that either accident or design could possibly have produced such an end by means so various and complicated, and to which no other art, (save in the use of the camera obscura,) has the least analogy in the manner in which the object is accomplished.

This being a subject of considerable public interest, and, withal, a strictly philosophical art, we shall here describe all the manipulations as they succeed each other in producing the result, a human likeness.

The whole process may conveniently be divided into eight distinct operations. 1st. Polishing the plate. 2d. Exposing it to the vapor of iodine. 3d. Exposing it to the vapor of bromine. 4th. Adjusting the plate in the camera obscura. 5th. Exposing it to the vapor of mercury. 6th. Removing the sensitive coating. 7th. Gilding the picture. 8th. Coloring the picture.

1. *Polishing the Plate.*—The plates are made of thin sheets of silver, plated on copper. It is said that for some unknown reason the photographic impression takes more readily on these plates, than on entire silver. The silver is only thick enough to prevent reaching the copper in the process of scouring and polishing.

The polishing is considered one of the most difficult and important manipulations in the art, and hence hundreds of pages have been written to describe the various methods devised and employed by different artists or amateurs.

We can only state here, that the plate is first scoured with emery to take off the impressions of the hammer in *planishing*; then pumice, finely powdered, is used, with alcohol, to remove all oily matter, and after several other operations, it is finally given the last finish by means of a velvet cushion covered with rouge.

2. *Iodizing the Plate.*—After the plate is polished, it is instantly covered from the breath, the light, and the air, nor must it be touched, even on the edges, with the naked hand; but being placed on a little frame, with the face down, it is carried to a box containing iodine, over which it is placed as a cover. Here it remains for a moment or two in a darkened room, being often examined by the artist, whose eye decides by the yellowish color to which the silver changes, the instant when the metal has combined with the proper quantity of iodine. This is a very critical part of the process, and requires a good eye and much experience. The vapor of iodine forms a film of the iodid of silver on the metal, and it is this which makes it sensible to the light of the camera, by which the picture is formed. If the film of iodine is too thick, the picture will be too deep, and dark; if too thin, either a light impression, or none at all, will be made.

3. *Exposure of the Vapor of Bromine.*—Bromine is a peculiar substance, in the liquid form, of a deep red color, exceedingly volatile, very poisonous, and having an odor like chlorine and iodine, combined. It is extracted from sea water, and the ashes of marine vegetables.

This the photographic artists call an *accelerating* substance, because it diminishes the time required to take the picture in the camera obscura.

The iodized plate will receive the picture without it, but the sitter has to remain without motion before the camera for several minutes, whereas by using the bromine, the impression is given, in a minute, or in a minute and a quarter. Now as the least motion in the sitter spoils the likeness, it is obvious that bromine is of much importance to the art, especially to nervous people and children.

The bromine is contained in a glass vessel closely covered, and is applied by sliding the plate over it for a few seconds.

4. *Adjusting the Plate in the Camera.*—The plate is now ready for the photographic impression by means of the camera. If a likeness of a person is to be taken, he is already placed before the instrument, in a posture which the artist thinks will give the most striking picture, and is told that the only motion can make for a half a minute to a minute, is *winking.*

The artist now takes the plate from a dark box, and under cover of a black cloth fixes it in the focus of the lens. This is done in a light room, with the rays of the sun diffused by means of white curtains.

The artist having left the sitter for the specified time, returns, and removes the plate for the next operation. Still, not the least visible change has taken place on the bright surface of the silver. If examined ever so nicely, no sign of a human face is to be seen, and the sitter who sees the plate, and knows nothing of the art, wonders what next is to be done.

5. *Exposure to the Fumes of Mercury.*—The plate is next exposed to the fumes of mercury. This is contained in an iron box in a darkened room, and is heated by means of an alcohol lamp, to about 180 degrees, Fah. The cover of the box being removed, the plate is laid on, with the silver side down, in its stead.

After a few minutes, the artist examines it, and by a faint light now sees that the desired picture begins to appear. It is again returned for a few minutes longer, until the likeness is fully developed.

If too long exposed to the mercury, the surface of the silver turns to a dark ashy hue, and the picture is ruined; if removed too soon, the impression is too faint to be distinct to the eye.

6. *Removal of the Sensitive Coating.*—The next operation consists in the removal of the iodine, which not only gives the silver a yellowish tinge, but if suffered to remain, would darken, and finally ruin the picture. Formerly this was done by a solution of common salt, but experiment has shown that the peculiar chemical compound called *hyposulphate of soda*, answers the purpose far better. This is a beautiful transparent crystalized salt, prepared by chemists for the express purpose.

A solution of this is poured on the plate until the iodine is entirely removed, and now the picture, for the first time, may be exposed to the light of the sun without injury, but the plate has still to be washed in pure water, to remove all remains of the hyposulphate, and then heated and dried over an alcohol lamp.

7. *Gilding the Picture.*—This is called, *fixing*, by the chloride of gold.

Having washed the picture thoroughly, it is then to be placed on the fixing stand, which is to be adjusted previously, to a perfect level, and as much solution of chloride of gold as the plate can retain, poured on. The alcohol lamp is then lish-

; to

under all parts of it successively. At first the image assumes a dark color, but in a few minutes grows light, and acquires an intense and beautiful appearance.

The lamp is now removed, and the plate is again well washed in pure water, and then dried by heat.

Before gilding, the impression may be removed by repolishing the plate, when it is perfectly restored; but after gilding, no polishing or scouring will so obliterate the picture, as to make it answer for a second impression. Such plates are either sold for the silver they contain, or are re-plated by the electrotype process.

8. *Coloring the Picture.*—Coloring daguerreotype pictures is an American invention, and has been considered a secret, though at the present time it is done with more or less success by most artists.

The color consists of the oxyds of several metals, ground to an impalpable powder. They are laid on in a dry state, with soft camel-hair pencils, after the process of gilding. The plate is then heated, by which they are fixed. This is a very delicate part of the art, and should not be undertaken by those who have not a good eye, and a light hand.

The author is indebted to Mr. N. G. Burgess, of 192 Broadway, New York, for much of the information contained in the above account of the daguerreotype art. Mr. B. is an experienced and expert artist in this line.

MORSE'S ELECTRO-MAGNETIC TELEGRAPH.

375. The means by which Mr. Morse has produced his wonder-working and important machine, is the production of a temporary magnet, by the influence of the galvanic fluid.

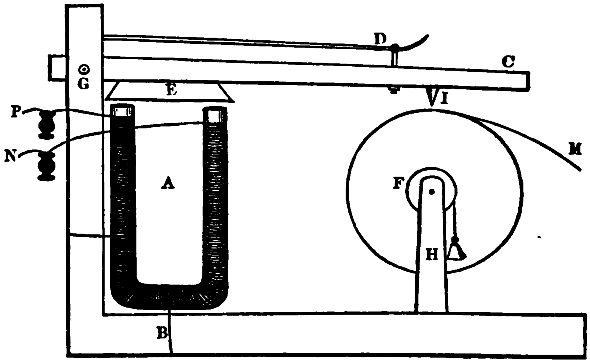
We have already described the method of making temporary magnets of soft iron, by covering the latter with insulated copper wire, to each end of which the poles of a small galvanic battery is applied.

The description of *Fig.* 289, with what is said before on the subject, will inform the student how the power is obtained by which the philosopher in question has brought before the world such wonderful and unexpected effects.

The machine itself is sufficiently simple, and will be comprehended at once, by those who have made electro-magnetic experiments, by the annexed diagram and description.

The temporary magnet A, *Fig.* 292, enveloped with its insulated copper wire, is fastened to the wooden frame B G, by means of cords or otherwise.

FIG. 292.



Principle of Morse's Telegraph.

This frame also supports the standard H, which sustains the revolving drum F, on which the paper to receive the emblematical alphabet is fixed, M being the edge of the paper.

To the arm G, is appended the lever C, of wood, which has a slight vertical motion, in one direction by the steel spring D, and in the other, by the armature of soft iron E.

The two poles of the magnet rest in two little cups of mercury, into which are also to be plunged the poles of the magnetic battery, (not shown in the drawing,) of which P is the positive, and N the negative. The steel point I, attached to the lever, is designed to mark the telegraphic alphabet on the paper.

Having thus explained the mechanism, we will now show in what manner this machine acts to convey intelligence from one part of the country to another.

It has already been explained that when a bar of soft iron surrounded by insulated copper wire, as shown at A, has its two poles connected with the poles of a galvanic battery, the iron instantly becomes a magnet, but returns to its former state, or ceases to be magnetic, the instant the connection between them ceases.

To break the connection, it is not necessary that both of the poles should be detached, the circuit being broken by the separation of one only.

Supposing then, that N and P are the poles of such a battery, on placing N into the cup of mercury, the wires from the soft iron being already there, the armature E is instantly tracted, which brings the point I against the paper on the revolving wheel F. If N is instantly detached after the point strikes the paper, then only a dot will be made, for the magnetic power ceasing with the breaking of the circuit, the spring D withdraws the point from the paper the instant the pole is removed.

If a line is required in the telegraphic alphabet, then the pole is kept longer in the vessel of mercury, and as the alphabet consists of dots, and lines of different lengths, it is obvious that writing in this manner can not be difficult. The understanding of the alphabet is another matter, though we are informed that this may be done with facility.

The marks of the point I, are made by indenting the paper, the roller on which it is fixed being made of steel in which a groove is turned, into which the paper is forced by the point. The paper is therefore raised on the under side like the printing for the blind.

The roller F is moved by means of clock-work, having an uniform motion, consequently the dots and lines depending on the time the point is made to touch the paper, are always uniform.

Now with respect to the distance apart at which the temporary magnet and writing apparatus, and the battery are placed, experiment shows that it makes little difference with respect to time. Thus, suppose the battery is in Hartford, and the magnet in New York, with copper or iron wires reaching from one to the other. Then the telegraphic writer at Hartford, giving the signal by means of an alarm bell, that he is ready to communicate, draws the attention of the person at New York to the apparatus there—the galvanic action being previously broken by taking one of the poles from the battery at Hartford.

If now we suppose the letter A is signified by a single dot, he at Hartford dips the pole in the cup of the battery, and instantly at New York the soft iron becomes a magnet, and a dot is made on the paper, and so, the rest of the alphabet.

The wires are carried through the air by being wound around glass caps supported by iron L shaped arms, which are driven into wooden posts about 20 feet from the ground. These posts are erected for this purpose chiefly on the railway lines from 50 to 100 feet apart.

VELOCITY OF ELECTRICITY.

376. The long experience of the officers of the United States government on the coast survey, with telegraphic lines, have

enabled them to measure the velocity of the galvanic current with uncommon accuracy. From experiments and calculations thus made, it appears that its velocity is about *fifteen thousand four hundred miles per second.*

The period of its transit between Boston and Bangor, was recently measured, and the result was, that the time occupied in its passage, was the *one hundred and sixtieth of a second.* According to this experiment the velocity is at the rate of 16,000 miles per second, which it appears is about 600 miles per second more than the estimates made on the coast survey.—*Annual Scientific Discoveries.*

Telegraphs in the Country.—According to a recent estimate, the length of telegraphic lines in the country, in actual operation, is not far from 15,000 miles.

The most remote points in communication are Quebec and New Orleans; their distances apart, following the circuitous routes of the wires, being about 3,000 miles.

Number of Stations.—The number of towns and villages accommodated with stations, and from which, therefore, intelligence by telegraph, from one to the other, or from one to all the others can be interchanged, are between 450 and 500.

MORSE'S TELEGRAPHIC ALPHABET.

Alphabet.	Alphabet.	Alphabet.
A - —	N — -	& - ---
B — ---	O --	
C -- -	P -----	Numerals.
D — --	Q -- — -	1 - — — -
E -	R - --	2 -- — --
F - — -	S ---	3 ---- — -
G — — -	T —	4 ---- —
H ----	U -- —	5 — — —
I --	V --- —	6 ------
J — - — -	W - — —	7 — — --
K — - —	X - — --	8 — ----
L ——	Y -- --	9 — -- —
M — —	Z --- -	0 ———

HOUSE'S PRINTING TELEGRAPH.

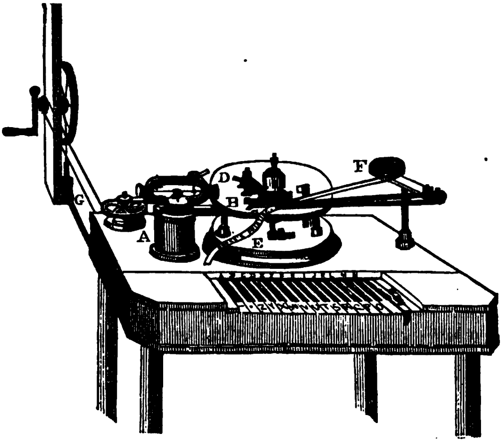
377. This instrument, one of the wonders of our time, prints all communications in Roman capitals, and that much more rapidly than the most expert compositor.

To go into a description of all its parts would probably so confuse the mind of the reader, that in the end none of it would be understood. We shall, therefore, describe only such portions of the machinery as are necessary to show how the result is produced.

In the first place, when a communication is to be made from one city to another, notice is given, by an electrical current on the wires, which occasions a vibration of a part of the machinery, and by which the attendant knows that a message is to be sent. At every station there is an electrical battery, consisting of 12 or 14 cups, the power most commonly used being that known as Grove's battery, a description of which may be seen in another place.

The forms of all visible parts of the instrument are shown by *Fig.* 293. That portion by which the printing is performed consists of a soft iron, or electro-magnet contained in the cylinder A, of an escapement B, moved by condensed air, by means of the pump G, above which is seen the band by which that part of the machinery is turned; D is the printing apparatus, the projecting portion being the lever; E is the inking band, by which the type are inked for printing; F is a strip of paper for printing.

FIG. 293.



House's Printing Telegraph.

This engine is moved by a boy, who turns the wheel by the lever shown, and by which air is condensed by the pump G, and by the force of which, the printing portion of the machinery is actuated.

The action of the electricity in this telegraph is merely to produce a correspondence of motion in the machinery at the different ends of the line. All the mechanical results are produced by local, mechanical power, connected with the printing apparatus at each station, where manual force is employed for this purpose.

378. The letters on the keys, moving by the touch like those of the piano, are the instruments by which the different letters are, one by one, printed from one station to the next. Thus one letter of the 26, on the different keys, will be printed at the other end of the line, when that letter is depressed. This is done by converting a piece of soft iron into a magnet at the next station, on the principle already explained and illustrated, in the description of Morse's telegraph, only that the letter, instead of the point, is made to act or advance.

This is a most complicated machine as a whole, though its different parts are sufficiently simple. The effect, though the means are so difficult to understand, is highly curious and interesting, as it prints Roman capitals at the rate of 150 or 200 in a minute. This is done on strips of paper an inch wide; and when in operation, any one may print a sentence, as his own name, by touching the keys on which the letters are placed, which spells the sentence.

PRINTING PRESS.

378. It is said that the Chinese printed from blocks of wood, with letters engraved on them, before the Christian era.

But the first printing on metallic type, was executed on the celebrated Mentz Bible, in about 1450. The next specimen of printing known was the Psalter, done in Germany, in 1457.

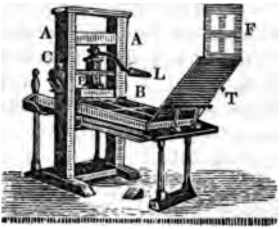
It is said that these books are printed in such a style of beauty and finish, as to command the astonishment of all printers who behold them, and that even at the present day, with all our boasted inventions and improvements in the arts, it is difficult to imitate, and hardly possible to excel, these as specimens of work in the art of printing.

Of the mechanical means by which printing has been, and still is performed, many singular and curious examples might be described, but our limits will only admit descriptions of two figures, representing Ramage's press and the cylinder press.

379. *Ramage's Press.*—This press was that most commonly used on both sides of the Atlantic, until within the last 20 years. In addition to this, the Stanhope and Smith presses were used

in England, and the Clymer and Washington in this country. These may be considered as varieties of the Ramage; and their description would possess no interest, except to the antiquated printer who had worked at them with the inking balls, now long since disused, as we shall see.

FIG. 294.



Ramage's Press.

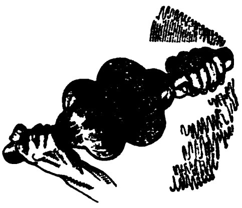
The Ramage press is represented by *Fig.* 294, and will be understood by the following description: The *cheeks* A A, are the sides of the wooden frame which supports the other parts, and sustains the force of the screw by which the impression is made. The *bed* B, is that part on which the type are laid for printing. The *ball* C is seen on a little shelf, called the *rack*, made for that purpose. [This will be described hereafter.] The *frisket*, F, turns down, and confines the sheet on the *tympan*. The *bar* or *lever* L, turns the screw by which the force is given and the impression on the type made. The *platen*, P, is fastened to the lower end of the screw, being the part by which the impression is made. It is of cast iron, about two feet square, thick at the center, and strong, so as to give a heavy force. The *tympan*, T, is covered with parchment to receive the sheet, confined by the frisket, and then run under the platen to be printed.

Action.—The type being set, and locked firmly in an iron frame, called a *form*, this is laid on the bed, and the type inked by the balls; the sheet is next laid on the tympan, and covered by the frisket, which has open spaces for the pages, as seen in the figure. The type and sheet spread over them, are then moved under the platen by the action of a lever, connected with a wooden cylinder, surrounded by leather straps, and called the *rounce*. The impression is then made by pulling the lever, by the action of which, on the screw, the platen is forced upon the paper, and this on the type. The bed is then "run out," the type again inked by *dabbing* with the balls, and the whole is again ready to be run in for another impression, and so on to the end.

INKING BALLS.

380. The former method of distributing the printing ink on the type, consisted in the use of a pair of *balls*, represented by

FIG. 295.



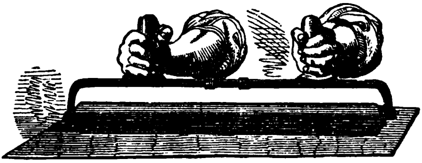
Inking Balls.

Fig. 295. These were made of sheeps' skin, undressed, and technically called *pelts*—were six or eight inches in diameter, stuffed with wool, and furnished with wooden handles.

One of these being struck on the board where the ink, a little thicker than cream, was spread, took up a small quantity, which, by turning the balls skillfully on each other, was equally spread over both. They were then taken, one in each hand, and *dabbed*, or rapidly struck on the type, until the ink was nicely distributed over their faces, and thus they were made ready to give an impression. This was a critical and laborious operation, requiring much experience and a strong arm, like that of a blacksmith, in order to cover the type speedily and equally with the ink. [Printer's ink is made of oil and lampblack.]

381. *Invention of the Roller.*—The ancient method of inking the type, as above described, was destined to give place to an improvement, which, among printers, formed an era long to be remembered.

FIG. 296.



Inking Roller.

This was the invention of the *roller* which is composed of *molasses*, *glue*, and *tar*, intimately mixed and combined by heat. This composition has all the qualities to be desired for this purpose, namely, softness, elasticity, and readiness to receive and impart the ink. This being cast into a cylinder, on a wooden support, and fitted to an iron frame, with handles, as shown by *Fig.* 296, form the important instrument in question.

Rollers have also been made of India rubber.

As the ends of the support revolve easily in the frame, all that it is necessary to do to spread the ink on the type, is first to pass the roller a few times over the board on which the ink is spread, and then revolve it over the type two or three times.

This invention completely obviated the most laborious and unpleasant portion of the art of printing by hand; and in machine printing, these rollers are so absolutely indispensable, that without them that mode of printing, without which the world would now remain in comparative ignorance, would have to be relinquished. These rollers are from two to eight inches in diameter; and for machine work, from three to six feet in length.

DOUBLE CYLINDER PRINTING MACHINE.

382. This printing press, when compared with the ancient or former one of Ramage, already described, will be seen to present an entirely new invention, or series of inventions; for many years were consumed in devising and adapting its several parts to each other, and bringing it to the state of perfection in which it now exists.

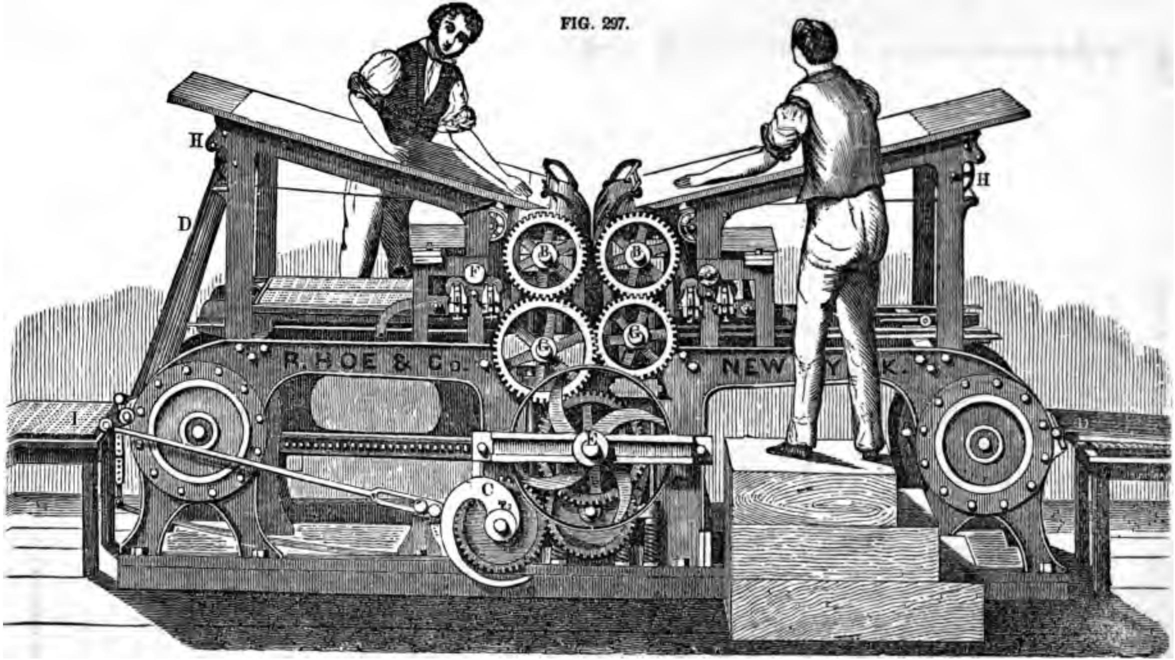
Instead of printing, as did the hand presses in old times, 2,000 copies a day, by means of ten hour's hard labor of two men, this engine, driven by steam, will, with the help of two boys to fix the sheets in their places, print from 3,000 to 6,000 sheets per hour, or from 30,000 to 60,000 copies per day. Such are the improvements in printing machines within the last twenty years.

283. *Description.*—This is a length, or side view of the machine; the length of the printing cylinders and inking rollers being about four feet. The length here shown of the whole machine, is from 8 to 10 feet, and the height to the upper cylinder 4 feet.

The ink, about the consistence of cream, is taken from the trough, which is of the length of the small, rapidly revolving roller, by which it is taken up, and from it is taken by adhesion to another and larger roller, from which it is derived by the type, over which it passes with a reciprocating motion.

At, or during each impression, the ink on the type is renewed by the continually revolving rollers. Thus, while this engine is in action, being generally moved by steam, nothing more is necessary than to supply the ink by putting it in the trough, and to place the ends of the sheets under the revolving cylinders, which latter work is done by two boys, as shown by the cut.

FIG. 297.



Double Cylinder Printing Press.

384. The parts of the press shown by the *Fig.* 297, are marked as follows: The *bed* A, on the left, corresponds to the same part in the hand press already explained. This has a reciprocating or in and out motion; the type which rest on it, being alternately run out to be inked, and run in to be printed. The *revolving cylinders* B B, receive the paper and press it upon the type, by which it is almost instantly printed. The *cam* C moves the *flies* D D, by which the printed sheets are carefully laid away in a pile. This movement is communicated by the cam to the flies, by the long iron bar seen on the left. The *pulley* E, moved by a strap connected with the steam power, gives motion to the entire machine by means of gearing. The *revolving wheels* G G, give motion to the cylinders and inking rollers. The *tape wheels*, so called, H H, are the wheels over which run tape bands, not shown, which convey the printed sheets from the form to the flies. The printed sheets shown at I, have been laid off by the flies, and are ready for circulation, or the bindery, as the case may be.

[The author has thus tried his best to give an idea of printing presses to those who never saw them; but he would advise all those who desire to know how printing is done, especially by a cylinder press, to go and see with their own eyes, which they can do now in nearly every village in the country.]

SHARP'S RIFLE.

385. This is undoubtedly for the purpose designed, the most perfect and efficient single instrument of destruction ever invented; and of which, we here propose to give such a description, with illustrations, as to make all its peculiarities readily understood.

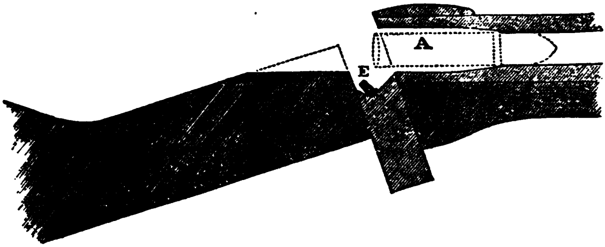
The *barrel* is about 22 inches long, and the bore of the size to admit round balls of 32 to the pound; but being elongated, or acorn-shaped, the number is only 18 to the pound.

This rifle loads at the breech, the form of the ball inclosed in its cartridge being shown at A, *Fig.* 298, introduced into its place.

The *slide* B, which takes the place of the breech pin in other guns, is a solid piece of steel, represented depressed for the introduction of the ball. The *cone* E, is that part on which the percussion cap, or its substitute, is exploded, and which inflames the charge in the gun.

The manner in which the breech slide is depressed, will be understood by the section, *Fig.* 299, where D is the lever by

FIG. 298.



Sharp's Rifle.

which it is drawn down for the introduction of the ball, and then elevated preparatory to the discharge. The upper and anterior portion of the slide, has a cutting edge, seen above B, *Fig.* 298, which separates the end of the paper cartridge, thus exposing the powder to the action of the percussion priming, by which it is inflamed and the gun discharged.

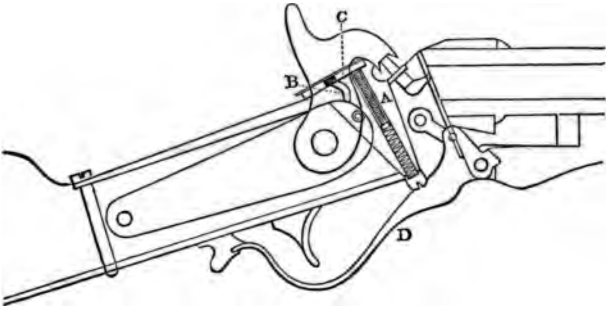
386. *The Priming.*—The former mode of discharging this rifle was by means of Maynard's patent priming, which consisted of kernels of percussion powder, inclosed in varnished paper. But this mode the inventor of the rifle found objectionable on several accounts, and especially as it became useless on exposure to moisture.

He therefore invented a new, and an entirely original mode of priming, which has been recently patented, and which he has allowed the author to figure, and explain for the use of this work.

This consists of the tube A, *Fig.* 299, of iron, about the one-fifth of an inch in diameter and two inches long, called the *magazine.* In the lower part of this is a spring, above which are the priming discs, consisting of thin, round envelopes of copper, containing the percussion powder, completely protected from moisture, so that they may remain under water for hours, or weeks, without damage.

Each tube holds 60 of these primers, one of which is forced up against the slide C by the spring. When the hammer is drawn to the back notch, the *slit* B, working on the arm of the *slide* C, which is fastened to the plate of the lock, draws it back from over the tube A, and admits one of the percussion discs in front of the slide at C, and by which, when the trigger is pulled, it is thrown forward, between the face of the hammer

FIG. 299.



Sharp's Rifle.

and the cone, where it is instantly exploded, and the rifle discharged.

One of the most singular and curious results of this mechanism, is, that the percussion disc is struck, as it were, "on the wing," or while it is flying between the hammer and the cone; and yet it never fails to explode in the proper place and discharge the gun, let its position be vertical or horizontal.

387. *Practical effects of this Rifle.*—We have seen this arm fired at a target at the several distances of 300, 500, 600, and 700 yards, being respectively 900, 1,500, 1,800 and 2,100 feet.

The target was a pine board 30 inches square, and by the inventor was hit on the average, twice out of three shots.

By experiments and calculations lately made in France, it was found that a man, at the distance of 1,638 feet, appears to the naked eye only one-fifth his real size, and therefore, by this estimate, a target of 30 inches in diameter, at the distance of 2,100 feet, appears less than six inches square, a small object truly in practice, and requiring an accuracy of aim so minute, that the tenth of an inch in the direction of the sight, would carry the ball far aside of such a mark, and yet it was pierced twice out of three shots.

388. *Adjusted Sight.*—This rifle has an adjusting sight, which is elevated, or depressed and fixed, according to the distance of the mark. All the shots were made, with the gun in the hands, or without a rest, and also, with the striking peculiarity of being placed on the left shoulder.

Fatal at the Distance of a Mile.—Although in the above trial, the distance was only 700 yards, the inventor has proved by experiment, that this rifle throws its ball with a force equal to the destruction of human life to the distance of a mile.

In battle, therefore, the approaching enemy can be effectually assailed with this arm, at that distance, the aim, of course, being more and more sure, as the distance diminishes.

Number of Balls Thrown.—The rapidity with which this arm may be loaded and fired is such, that if one ball be sent along the surface of water, another may be made to follow before the first ceases its motion.

The inventor loads and fires it ten times in a minute; but estimating that in battle the number of balls fired by each soldier would be only six in a minute, then 1,000 men would discharge 6,000 in a minute, or 360,000 in an hour.

389. *Invention of Gunpowder.*—In Europe, the invention of gunpowder is attributed to Roger Bacon, who died in 1292; but it seems to have been known to the Chinese long before that period.

The first account of its use in European war, was at the battle of Cressy, in 1346, and from that time it superseded, chiefly, all other means of destruction on the battle-field.

Effects of this Invention.—There is no doubt but this invention has proved a humane—a merciful discovery in the art of war.

Before its use, the instruments of death in battle were the barbed arrow, the halbert and spear, various kinds of swords, and the war-club.

The combatants fought hand to hand, each one trying to inflict the most cruel tortures on the other; and, indeed, the instruments employed, were much better calculated for this purpose, than for the infliction of sudden and quiet death.

On the contrary, gun-shot wounds, when not instantly fatal, afford a prospect of recovery, while those made by the barbed arrow and spear, more commonly portend a miserable death, after protracted agony.

Besides, if we examine the accounts of ancient battles, we shall find, that including the carnage on the field, and the number who died of their wounds afterward, the destruction of human life, where an equal number were engaged, was much greater than it was, after the invention and use of gunpowder.

390. *Conclusion.*—Although there is no doubt but the use of fire-arms, in warfare, has heretofore diminished the horrors of the battle-field, this circumstance, as history informs us, has

had no influence on our species, except to foster an increasing desire to render the instruments of death more and more perfect, so that in the day of battle, the carnage should be as sudden and as great as possible. And hence, within a few years, great improvements have been made on fire-arms in France, England, Germany, and America, all tending of course, to the increase of their destructive effects.

The inventors of these improvements in the arts of human destruction, are by no means considered by political, or even by moral and religious writers, as enemies of the human race, but are viewed, at least, by many such, as the pioneers of universal peace, if, indeed, fallen man should ever cease to learn and practice the art of war.

391. *Settlement by Arbitration Improbable.*—The history of man affords no foundation for the belief that national quarrels will be settled by the intervention, or arbitration of other nations, and hence, there can be little doubt, if the moral and political condition of the world remain as heretofore, that "nation will continue to lift up its arm against nation," and that the time when "man shall learn war no more," is *not* at hand, unless indeed, it should be by the approach of the millenium.

Under this view of the case, the only prospect of universal and permanent peace, is in such a degree of perfection in the art of war, that certain death awaits at least five out of six of all who enter as combatants on the field of battle; and in naval warfare, an equal proportion of ships shall as certainly be buried in the ocean.

Until such a state of things exist, men will continue to engage each other in mortal strife; and it is on this account that moralists of the present day, look with favor on the improvements in fire-arms, knowing that the paramount design of all such inventions is to render escape more difficult, and death more sudden and certain on the battle ground.

Nor is it probable that the time is far distant, when at least ten will fall on the field, where with an equal number of combatants, only one fell 30 years ago; the result being solely from the more deadly power of the fire-arms employed.

The author having served as surgeon on the frontier, in the U. S. Army, in the war of 1812–15, is able to appreciate, in a measure, the difference between the destructive power of the fire-arms then furnished by the government, and those now to be introduced into the Army of the United States.

392. *Contrast between Old and New Arms.*—To those who

have examined this subject, and are acquainted with the arms employed formerly, and those now going into general use, it will not be considered an over estimate to suppose, that 100 men armed with Sharp's rifle, and Colt's revolvers, would commit greater carnage, on the battle ground, than 1,000 men could do, with the flint lock, government muskets, in former use.

393. Who indeed will enlist into a military service when he knows that his enemy will oppose him with messengers of death, at the rate of 600 per minute, or 36,000 per hour, for every 100 men, and this at the distance of a mile, or less; and with the same number of such messengers, in half that time, when within any distance between 20 yards, and the reach of the bayonet; which will be the case when armies are supplied with Sharp's rifles, and Colt's revolvers.

From such sources only, according to the present aspect of the nations of the earth, can we look for permanent peace.

COLT'S REPEATING PISTOL.

394. This celebrated fire-arm has been brought to its present degree of perfection, only after years of experience, trial, and invention, by the original patentee Col. Samuel Colt, of Hartford, Conn.

An account of this weapon is introduced here, as an invention with which all the civilized nations of the earth, are now, or are soon, to become acquainted.

As Americans, therefore, we are bound to know something, at least, of the history and mechanism of so important an invention.

The examination and trial of Colt's revolvers at the World's Fair, and the award passed upon them there by the best judges, and the most experienced military men of the age, are ample, and sufficient proofs that this, for the purpose for which it is designed, is the most efficient and perfect fire-arm ever invented.

The immense demand for the article in foreign countries, as well as in our own country, evinces, also, that no substitute exists for this weapon.

About 400 artificers, we understand, are employed in their manufacture, which number, it is stated, is to be increased to 1000, in order to supply the demand.

The United States government have adopted Colt's repeating pistol, as the best weapon known, for mounted men, both for offensive and defensive use. And in the Mexican war, no officer who could obtain a revolver, ever went a day without one, and those who could not, often considered their lives in peril, in consequence.

395. In 1851, the President of the United States in a message to the Senate, states, that

"Such is the favorable opinion entertained of the value of this arm, particularly for mounted corps, that the secretary of war has contracted with Mr. Colt, for four thousand of his pistols," without waiting a special appropriation of Congress.. This contract, of course, was confirmed by the Senate.

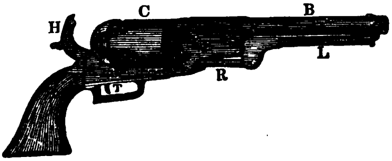
Such is considered the importance of this arm as a weapon of defence, that the military committee of the House of Representatives, recommend that it should be furnished to emigrants, as the following shows.

"We, the undersigned, members of the military committee of the House of Representatives, understanding that an application is pending before your committee, favorably commended by the ordnance department, for the purchase of a suitable number of Colt's pistols, and authorizing the department to furnish the same to emigrants at government prices, and to deliver the same to the States, under the act of 1808, for arming the militia, recommend the same to your favorable consideration, and believe that such a clause in the army bill would be desirable and proper."

Signed by the committee, nine in number, January, 1851.

396. *Description of Colt's Pistol.*—Why these arms are called *revolvers*, and by what means they are made the most efficient of fire-arms, for certain purposes, will be understood by *Fig.* 300, and the following explanation.

FIG. 300.



Colt's Pistol.

The letters by which the principal parts of the pistol are denoted, are the following, as seen on the cut. The *barrel* B, is from three, to eight inches in length according to the size and design of the pistol. The *cylinder* C, is the part which revolves, and from which the arm takes its distinctive name. The mechanism by which the rotary motion is performed, can not be shown by a single figure. The cylinder is pierced with six apertures, called *chambers*, each of which, when ready for action, contains a charge of powder and a ball. Caps are then put on the tubes, corresponding to each charge, and now the arm is ready for the discharge of six balls, as rapidly as the hammer can be drawn to the back notch and the trigger pulled.

The *hammer* H, being drawn back to where it now stands, is made to strike, with its face, the cap on the tube, by which it is exploded, and the pistol discharged. Then on drawing the hammer back for another discharge, the mechanism makes the cylinder revolve *one notch*, by which the next cap is brought under the hammer, and by pulling the trigger is discharged, and so of all the other charges. The *trigger* requires no explanation, being in all fire-arms the same. The *ramrod* R, is connected with the *lever* L, by the united action of which, the ball is pushed down the chamber to the powder.

397. Having explained the references, we will give the inventors own directions for loading, &c.

"Draw back the hammer to the half notch, which allows the cylinders to be rotated; a charge of powder is then placed in each chamber, and the balls, without wadding, or patch, are put, one at a time, upon the mouths of the chambers, turned under the rammer, and forced down with the lever below the mouth of the chamber. This is repeated until all the chambers are loaded. Percussion caps are then placed on the tubes, when, by drawing back the hammer to the full catch, the arm is in condition for a discharge by pulling the trigger; a repetition of the same motion produces like results."

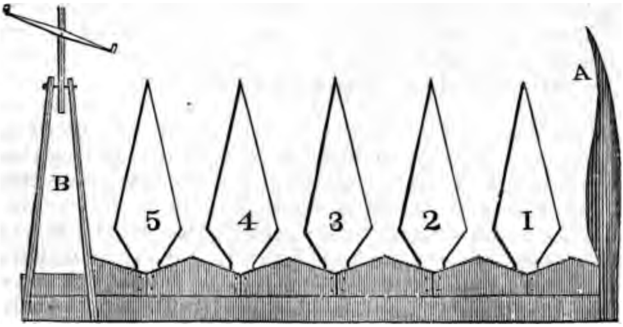
When this arm is prepared, therefore, all that is required in defence, or in action, is to draw back the hammer, and pull the trigger, until the six balls are discharged, which is done in less than half a minute.

MC CORMICK'S REAPER.

398. The *principal*, or cutting apparatus of this famous machine, is shown by *Fig.* 301. The entire machinery, consisting not only of the four wheels on which the whole rests, but also of bands, cranks, cog-wheels, driver's seat, and platform for the grain—the whole being connected and supported by braces in all directions; it is obvious, is too complicated an engine for the purposes of a school book.

Nor are these parts necessary to show the mystery, in which the public are chiefly interested, viz., how it is possible that a

FIG. 301.



McCormick's Reaper.

machine drawn by horses, can do what only the hands of man have heretofore performed with the sickle and cradle.

The above drawing is designed merely to illustrate and explain this wonder.

The angular pointed projections, marked by numbers 1, 2, 3, 4, and 5, are called the *fingers.* They are firmly driven into a beam of wood, at the distance of 4½ inches from the center of one to that of the other, and their length is about the same number of inches. They are of cast iron, without cutting edges.

At the base of the fingers, and between their angles, are seen the *sickles*, angular in form, and composed of sections of steel plate riveted to an iron strap, about an inch wide, which strap is movable to the right and left on the beam of wood into which the fingers are driven.

399. The sickles have thin cutting edges, which are finely serrated, similar to a common sickle, the teeth standing right and left from the center or angle of each.

While the fingers are fixed to the beam, the sickles have a reciprocating motion of about 4 inches, alternately to right and left by means of a crank, turned by the force of the wheels, by which the whole machine is moved.

This is the effective or cutting portion of McCormick's reaper. All the other parts are adjuvants to this, being the means by which this is moved and actuated.

The *divider* A, is a piece of iron which extends forward of the fingers, and is designed to separate the grain to be cut fr that which is to be left standing. This, as its shape indic bends the grain to be cut inwards, leaving that which remains in a well-defined and perfect line, until the return of the reaper.

The strips of wood, B, fastened to the beam on which the sickles work, show where the force, by means of horses, is applied, and by which the whole is drawn on four wheels of moderate size.

400. *Action of the Reaper.*—It will be observed that the effective or cutting portion of the machine, extends to the right of the place where the moving force is applied, and hence that the horses work on the side of the standing grain.

The grain, therefore, is cut by beginning on the outside and going around the field, the horses passing that which has been cut, while the sickles extend about six feet into that which is standing.

The cutting is performed by the alternate, or reciprocating motions of the sickles against the grain. which is kept from receding by the oblique, angular form of the fingers, as shown by the figure, after the inspection of which, no further description will be required to show how the operation is performed.

As the grain is cut, it falls upon a platform, where a man stands, with a rake, to gather and remove it to the outside of the machine, and where it is bound by men who follow for this purpose. Thus the way is cleared for the return of the horses and reaper.

It is stated that the fields of wheat thus cut, present a very smooth and, to the eyes of the farmer and others, beautiful appearance—the stubble presenting a level and even surface throughout.

The inventor of this reaper not only received the highest premium at the World's Fair, in England, but also the gold medal in the States of Ohio and Illinois, for the most complete, and best working machine of this kind presented.

It is stated that such is the demand for this reaper, that several thousands will probably be sold in the course of the present year. The price is about $120.

The inventor also constructs mowing machines, on the same principle as the reaper.

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Errata, Astronomy, p. 114, insert the Asteroids as in p. 120. In p. 122, omit the last clause, and look to Saturn for the correction. The relative size of Neptune can not be shown on the page.